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THE NEWCOMEN SOCIETY

for the study of the history of

ENGINEERING and TECHNOLOGY

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TRANSACTIONS

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1920-1921

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Introduction to the Literature of Historical Engineering to the Year 1640.

By E. Wyndham Hulme.

(Read on November 5th, 1920, at H.M. Patent Office, London.)

Inasmuch as Engineering and Technology are the mechanical foundations of all civilization, it is to the industrial history of primitive and prehistoric peoples that we must look for its first beginnings. The evidence of primitive industry is valuable because it gives us a picture of tribal life as a whole. That of prehistoric archaeology is much wider because it deals with past civilizations in all stages of their development. From it alone are we able to put together a connected history of man and his industries. But this reconstruction is necessarily a one-sided one —for it is based upon the survival of what our ancestors would have described as fossil remains, *i.e.*, a few unalterable substances such as pottery, glass, stone and the metals. Direct evidence of the perishable and immaterial things has been withheld from us.

The literature relating to primitive races I must dismiss by referring you to such works as Mason's Origin of Industries amongst Primitive Tribes, and Abbott's Primitive Industries of North America, while for prehistoric archæology you cannot do better than consult the excellent British Museum Guides to the Stone, Bronze and Early Iron Ages respectively. Here I would draw your attention to the fact that while the Bronze Age shows a high degree of technical attainment in the casting of the more fusible metals, the early Iron Age remains the age of wrought iron from approximately 1500 B.C. to 1400 A.D., a period of nearly 3,000 years. When and where the first casting of iron took place, I leave to our experts in iron metallurgy to tell you. There can, however, be little doubt that it was the need for cast iron ordnance that led to the introduction of this process in Western Europe.

Of greater interest for the history of civil engineering are the results which archæological research has yielded in Egypt, Asia Minor, Greece and Crete. Egyptological research owes a deep debt of gratitude to Napoleon for the magnificent survey of the history and antiquities of Egypt published between the years 1809-28 in 22 ponderous volumes of text and atlas under the title of "Description de l'Egypte." Interest for a time then shifted to the recovery of the buried cities of Pompeii and Herculaneum. But it was the discoveries of Schliemann be-

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tween 1870 and 1880, first at Troy and then at Mycenæ, which gave the impetus to the scientific studies of classical archæology which has recovered for us the history of the civilization of Crete which forms the connecting link between that of Egypt and Greece. The engineering problems of irrigation and water supply were, it is well known, solved at an early period by the engineers of Asia and North Africa, but in the great Palace of the Two Axes in Crete there has recently been discovered a system of water-carried sewerage and terra cotta socketed drain pipes which could not be paralleled in Europe prior to the end of the 18th century.

For a summary of these ancient civilizations, I can give you two excellent works by the American Egyptologist Breasted—the first entitled "Ancient Times"—a history of the early world, and the second which is just issued—"The Origins of Civilization."

Coming to the classical and the late classical period, we find the first works of strictly technological importance. The names of Aristotle, Ctesibius, Hero of Alexandria, Archimedes and Vitruvius stand out pre-eminent, but unfortunately we do not possess in all cases that full and authentic evidence as to their inventions which we require. The fame, for instance, of the inventions of Archimedes rests upon tradition. Sir Thomas Heath says that Archimedes disdained to record them as being beneath the dignity of a philosopher. Ctesibius was the son of a barber who demonstrated his professional skill to clients by suspending a mirror from chains, to one end of which was attached a weight working in a tightly-fitting case. The weight as it descended compressed the air, which, as it escaped, made an audible sound, and this suggested to Ctesibius the hydraulic organ. His name is also associated with the double-acting manual fire-engine which was introduced into Europe in the 16th century. But of his writings, if such existed, not a line has come down to us—though his inventions are probably largely embodied in the works of his pupil Hero of Alexandria. The drawings in the latter's works are with two exceptions based upon originals—but those of Vitruvius are all modern reconstructions from the text—a fact which should be borne in mind when you consult his tenth book, which deals with machinery.

One of our members, Dr. Lones, has published a scholarly treatise on the teachings of Aristotle on natural science. We should welcome from him a paper on the teachings of Aristotle and his school in mechanics and applied science, for few of our members possess Dr. Lones's double qualification of classical scholarship and proficiency in modern technological processes. The great defect in our modern histories of inventors and engineers is that they have for the most part been written by men whose scholarship has not atoned for the lack of professional knowledge of the subjects with which they have elected to deal.

There are, however, some good modern works dealing with the engineering history of the classical period. Amongst my exhibits will be found a work by Mr. G. F. Zimmer, a Member of our Society, who describes himself in his preface

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as "an Engineer by profession and an Archæologist by inclination." This description admirably defines the two-fold qualification for Membership in this Society.

The Middle Ages may be characterized as the period in which the artist rose superior to and dominated the engineer and scientist. Here we find bodies of workmen of mixed nationalities, moving from place to place and country to country working harmoniously in the service of Church or State, and instinctively solving the problems which the constant changes in architectural style and decoration demanded of them. Of them we may say they "builded better than they knew"; for throughout this period they never appear to have felt the need for analysing or reducing to system the principles upon which they worked. From the bibliographical standpoint we have to record a blank. Science, it is true, is represented by MSS. on Alchemy, Medicine, Mathematics, Geometry and Optics, but no great material progress is recorded. On the other hand, the Fine Arts are more worthily represented by various collections of receipts, of which the Treatise of the monk Theophilus and collections of Mrs. Merrifield are the most notable. But the only MS. which appears to recognise the needs of the time for some approach to methodical instruction in technology is the Sketch Book of Wilars de Honecourt, an Architect of the 13th century.

Honecourt's book, it is true, is little more than an architect's notebook, but it did contain, and its author attached special importance to, certain mechanical drawings, four of which, alas, have disappeared from the original MS. His preface runs—

"Wilars de Honecourt salutes you, and implores all who labour at the different kinds of work contained in this book to pray for his soul and hold him in remembrance. For in this book may be found good help to the knowledge of the great powers of masonry, and of devices in carpentry. It also shows the power of the art of delineation, the outlines being regulated in accordance with Geometry." This work is notable as the forerunner of a class of engineering sketch books which became popular in the 16th and 17th centuries.

In the absence of any systematic mediæval treatises on the subjects of mechanics and engineering construction, we are thrown back upon the incidental illustrations with which the MSS. of the Middle Ages are embellished. Fortunately this material, unsatisfactory as it is in its evidential quality is abundant in quantity, and has proved a rich storehouse of information which has been carefully sifted and classified by many writers. I will mention only Parmentier's "Album Historique," where the arrangement is chronological by countries; and Feldhaus's "Technik der Vorzeit," which is in dictionary order. There is a small guide to the illustrations in the British Museum MSS. by Birch and Jenner, and there is also a General Index of Names of Persons and Places and to some extent of Subjects in the entire literature of the Middle Ages by Chevalier in four vols.

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The English works by Wright, Cutts and others you are probably familiar with.

In the 15th century the obscurantism of the Middle Ages begins to dissolve under the influence of the new arts of artillery and printing. The development of artillery brought about changes in military tactics, ballistics, fortification, metallurgy and the mechanics of lifting and transporting heavy weights. The result is to be seen in the German MSS. reproduced by Berthelot illustrating the methods of attack and defence employed in the Hussite War c. 1430, the illuminated MS. of Valturius, and the anonymous German "Hausbuch," c. 1480, with its remarkable drawings, some of which are of a mechanical nature. On the other hand, the invention of printing from movable types, coupled with the recovery of many classical MSS., led to the printing of editions of the classical writers on mechanics with whom we have already dealt. It is true that the professional instinct of secrecy died hard. Da Vinci, for instance, the greatest artist, engineer and inventor of all ages, published nothing in his lifetime and committed his text to writing in cypher—by writing in reverse. His sketch-books, here represented by the collotype edition of the Milanese MSS., have only recently been reproduced—other MSS. still await publication. The printing press in the 16th century at last broke down the professional reserve, with the result that the technological literature of this century is probably equal in bulk and superior in merit to that of the following one. Thus we have the works of Agricola "De re metallica," of Biringuccio on pyrotechny, or as we should call it to-day metallurgy, and of Ercker on assaying. There is no parallel in importance to these three works in the technical literature of the 17th century except in the works of Moxon, the first English publisher of a series of technical handbooks issued in parts. Ercker's work on assaying was translated by Pettus a century later. Agricola has recently been translated into English and edited by the Hoover Brothers in a style worthy of the great writer; while Biringuccio, whose work was reprinted several times in the 16th and 17th centuries, as well as translated into French, has not yet appeared in an English version.

Then we have a series of folio engineers' sketch-books issued between 1569 and 1620 by Besson, Ramelli (1588), Veranzio (1590), Zonca (1607), Zeising (1621) and Strada (1617-18). Note the predominance of the Italian genius and the absence of English talent, which was still bent more upon copying foreign models than originating new designs.

There is, however, one great, perhaps the greatest mechanical invention of the age, which is unquestionably of English origin, viz., the Stocking Frame of Lee. Unfortunately the inventor, unable to obtain protection here, sought and secured encouragement in France. Then we have another great invention by an Englishman, the water-closet of Sir John Harington. Here the inventor, being a literary humourist, published his invention in the form of a prose burlesque on an unsavoury subject which he called the Metamorphosis of Ajax (*i.e.* a jakes).

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Bourne's Inventions or Devises (1578) and the works of Platt must not be overlooked, as affording evidence of the existence of a native inventive talent slowly coming to the front; and there is a folio work by Lucar Solis, a miscellany containing some original mechanical contrivances. Mr. Jenkins will show you a MS. collection of inventions by a military adventurer about the year 1590, which is, I think, worthy of reproduction by the Society if we adventure on such things. Finally, there are three classes of works to which I must briefly refer which became popular in the 16th century. (1) Histories of Inventions, (2) Books of Receipts and (3) Iconographies of the Arts and Trades. Of the first two classes, a careful bibliographical description exists in a series of papers by the late Prof. Ferguson of Glasgow. The histories of invention represented by the works of Polydore Vergil and his followers were popular snippets from early literature—they deal chiefly with the origin of human institutions and contain little of technical value. For the iconography of the arts and trades, the prototype is the well-known work of Jost Amman, which had many followers. The class of works he inaugurated degenerated into a form of chap-book literature in the early 19th century.

Finally, although this survey extends to the year 1640, I have deliberately abstained from dealing with writers on the subject of water-raising which, though they fall within my period, will be best treated by my successor in dealing with the forerunners of the steam engine.

In conclusion, I trust that this brief and imperfect survey has shown to students of historical engineering the need for research outside the narrow limits of technological literature. The field of historical engineering is as wide as that of history itself. All the auxiliary historical sciences must be pressed into your service. The study of coins, seals, heraldry, genealogy, inscriptions, the records of national and municipal administration—nay, even of literature itself may be necessary to complete the missing links in the chain of your historical investigations. For instance, the current number of the Journal of Philology contains under the form of a disquisition on the Latin word "arcus," a valuable contribution to the history of the drill and the origin of the lathe.

I hope, therefore, that this Society will collect and publish periodically references to the current literature of the subjects germane to it, with a view of widening the interests of its members and of enhancing the utility of the papers contributed to it. For bibliography is the corrective of old age. The constant supply of new ideas, gathered from all quarters, will prove the greatest incentive to new efforts on the part of our members and will tend to preserve the Society from premature decay.

Attention was directed by the author to the books that were there for inspection by the members; the books were some of those noted in the Appendix and had been drawn from the Patent Office Library for the occasion.

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In the discussion that ensued, Sir George Greenhill, Mr. Jenkins, Mr. Pendred, Mr. Reid, Eng.-Comm. Robertson, Mr. Sieveking and Mr. W. A. Young took part.

The meeting terminated with a vote of thanks to the Comptroller for the use of the Court Room.

Appendix.

Primitive Industries and Prehistoric Archæology.

Mason (Otis T.)
The origins of inventions: a study of industry amongst primitive peoples.
W. Scott, 1895. F'cap. 8vo.

Abbott (Charles C.)
Primitive industry . . . of the Northern Atlantic Seaboard of America.
Boston, 1881. 8vo.

British Museum Guides
Stone Age.
Bronze Age. 1920.
Early Iron Age. 1905.

Early Civilizations.

Description de l'Egypte
Paris, 1809-28. 10 vols., text, and 12 vols., atlas.

British Museum Guides
Egyptian Collections, 1909.

[Minoan Civilization]
Papers by S'r Arthur Evans and others. In Annual of the British School at Athens. Vols. VI. to XII., 1899-1906. Vol. VIII., pp. 13 and 82-7, deals with the drainage system of the "Palace of the Two Axes" at Knossos.

Breasted (James H.)
(1) Ancient Times, a history of the early world.
Ginn & Co., 1916.
(2) Origins of Civilisation.
In Scientific Monthly, Dec., 1919, to March, 1920. 134 figs.

Wells (H. G.)
Outlines of History. Illustrated edition.
Newnes, 1920. 2 vols.

Classical Civilization & Scholarship.

Veteres Mathematici
i.e., the collected works of Athenaeus, Apollodorus, Bito, Hero, Philo and others in Greek and Latin.
Paris, 1693. Fol. illus.

Heath (Sir Thomas)
Works of the Greek Mathematicians.
Cambridge, 1920. 2 vols.

Aristotle.
Oxford translation. Vol. VI. [includes the "Mechanics"].
Oxford, 1913. 8vo.
Aristotle's researches in natural science. By T. E. Lones.
West, Newman, 1912. 8vo.

Hero *of Alexandria, Pupil of Ctesibius*
Opera. Ed. Gul. Schmidt.
Leipzig, 1899, etc. *In progress.*
His Pneumatics, Automata and Mechanics are published.

Vitruvius
Zehn Bücher über Architektur. Uebersetzt und erläutert von J. Prestel.
Strassburg, 1912, etc. *In progress.*
N.B.—For plates *see* French edition of Perrault, or the editions of Newton (1791) or Wilkins (1812).

Blümner (Hugo)
Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern. 2te Aufl.
Leipzig, 1912. 4 vols., 8vo.
The standard work on the subject.

British Museum
Greek and Roman Life. Guide to the exhibition. 2nd ed.
London, 1920. 8vo.

Leger (Alfred)
Les travaux publics, les mines et la métallurgie aux temps des Romains.
Paris, 1875. Imp. 8vo, 12 folding plates.

Merckel (Curt)
Die Ingenieurtechnik im Alterthum.
Berlin, 1899. Imp. 8vo.

Diels (Hermann)
Antike Technik. Sechs Vorträge.
Teubner, 1914. F'cap. 8vo.
Deals with locks, steam engine, automata, alchemy, etc.

Zimmer (Geo. Fred.)
Engineering of antiquity.
Probsthain, 1913. Sm. 8vo.
Deals with the history of iron, conveyors, etc.

Middle Ages to 1400 A.D.

Honecourt (Wilars de) *Architect, 13th Century*
Sketchbook. Ed. R. Willis.
London, 1859. Sm. 4to.

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Parmentier (A.)
Album Historique. (Reproductions of mediæval drawings arranged in periods.)
Paris, 1897-1905. 3 vols., 4to.

Salzmann (L. F.)
English industries of the Middle Ages.
London, 1913. 8vo.
Compiled from the national Records; mostly new material.

Feldhaus (F. M.)
Technik der Vorzeit.
Leipzig, 1914. Large 8vo.
A dictionary of inventions, etc., from the Stone Age.

Chevalier (Ulysse)
Répertoire des sources historiques du Moyen Age. Bio- [and] Topo-bibliographie.
Paris, etc., 1903-9. 4 vols., large 8vo.

Turner (Hudson)
Some account of domestic architecture in England from the Conquest—Henry VII.
Oxford, 1851-9. 3 vols. in 4.

Addy (S. O.)
The evolution of the English House.
Sonnenschein. Sm. 8vo.
Has gone through many editions.

Innocent (C. F.)
The development of English Building Construction.
Cambridge, 1916. 8vo.

1400-1640. Engineers' Sketchbooks.

Vinci (Leonardo da)
Il Codice Atlantico.
Milan, 1884-1904. 3 vols., folio.
There is an extensive and growing literature on Da Vinci, for which consult the catalogues of the British Museum and Patent Office Libraries.

Deutscher Verein für Kunstwissenschaft (Berlin)
Mittelalterliches Hausbuch.
Leipzig, 1912. 4to.
Compiled about 1480. A book of receipts with drawings in the style of Durer. At the end are some valuable designs of machinery for raising weights, working bellows, etc.

Besson (Jac.)
Theatrum Instrumentorum et Machinarum.
Re-issued with explanatory text in 1578.

Ramelli (Ag.)
Le diverse et artificiose Machine del capitano Ag. Ramelli.
Paris, 1588. Folio.

Veranzio (F.)
Machinæ novæ.
c. 1590. Folio.

Zonca (V.)
Novo Teatro di Machine ed Edifici.
1607 [reprinted 1621 and 1656]. Folio.

Zeising (H.)
Theatrum Machinarum.
Leipzig, 1621. Folio.

Strada (J.)
Dessins artificiaulx.
1617-18. 2 vols. 8vo.

Beck (Th.)
Beitraege zur Geschichte des Maschinenbaues.
Berlin, 1900. 8vo.
Summarizes the work of the above writers.

1400-1640. Military Sciences—Fortification and Gunnery.

Berthelot (Marcellin)
Pour l'histoire des arts mécaniques et de l'artillerie vers la fin du moyen age (Reproduction of Munich MSS.), c. 1430.
In *Annales* de Chimie, etc., 6 Sér., Tome 24, 1891, pp. 433-521, illus.

Valturius (R.)
De re militari. (15th Cent. illuminated MS. in British Museum Library, printed in 1472 and often re-issued.)
Paris, 1534. Folio.

Cockle (Maurice J. D.)
Bibliography of English military books up to 1642 and of contemporary foreign works.
London, 1900. 4to. xlii., 268 pp., portrs., facs.
The English works are arranged chronologically; the foreign ones in class order. The preface is of great value.

Guttmann (Oscar)
Monumenta Pulveris Pyrii.
London, 1906. 4to.
Illustrated history of the development of gunpowder and ordnance.

Mechanics.

Del Monte (Guido Ubaldo)
Mechanicorum liber.
Pisa, 1577. Folio.
Transl. into Italian in 1581.

Branca (Giovanni)
Le Macchine.
Rome [1629]. Sm. 4to.

Mine Engineering and Metallurgy.

Biringuccio (V.)
Pirotecnia (*i.e.*, Metallurgy and allied industries, *e.g.*, wire-drawing, ordnance, etc.).
Venice, 1540. Sm. 4to.
Re-issued several times and transl. into French.

Agricola (G.)
De Re Metallica. Translated and edited by H. C. and L. H. Hoover.
London, 1912. Folio.
Original published at Basle in 1556.

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Ercker (L.)
Beschreibung allerfürnemsten Mineralien, etc.
Prag, 1574. Folio.

Water Raising, including the precursors of the Steam Engine.

Ceredi (G.)
Tre discorsi sopra il modo di alzar acque da' luoghi bassi.
Parma, 1567. Sm. 4to.

Porta (G. B.)
Le tre libri de' spiritali.
Naples, 1606. Sm. 4to.

Caus (Salomon de)
Raisons des forces mouvantes.
Frankfort, 1615. Fol.

Land Irrigation.

Vaughan (Roland)
His book [on water meadows].
1610. Reprinted 1897.

Surveying and Mathematical Instruments.

Kobel (J.)
Jacob's Stab.
Frankfort, 1531. Sm. 4to.

Warachtige Const der Geometryen, etc.
Antwerp, 1547. Sm. 4to.

Fullene (A.)
Holometro [geometric square].
Venice, 1563. Sm. 4to.

Bartoli (C.)
Del mode di misurare, etc.
Venice, 1564. 4to.

Belli (S.)
Libro del misurar con la vista, etc.
Venice, 1570. Sm. 4to.

Cataneo (G.)
Opera del misurare.
Brescia, 1572. 2 vols. Sm. 4to.

Lupicini (A.)
Discorso sopra la fabrica e uso delle nuove verghe astronomiche [surveyor's square].
Florence, 1582. Sm. 4to.

Orsini (L.)
Trattato del radio latino, etc.
Rome, 1583. 4to.

Digges (Leonard)
Pantometria.
London, 1592. Sm. 4to.

Pifferi (F.)
Monicometro, etc.
Siena, 1595. 4to.

Romano (B.)
Proteo militare [surveying instrument].
Naples, 1595. Sm. 4to.

Danfrie (P.)
Déclaration de l'usage du graphomètre.
Paris, 1597. 8vo. Printed in script type.

Fabri (O.)
L'uso del la squadra mobile, etc.
Venice, 1598. Sm. 4to.

Suberville (H. de)
L' Henry-mètre.
Paris, 1598. 4to.

Zubler (L.)
Fabrica et usus instrumenti chorographici [plane table.]
Basle, 1607. Sm. 4to.

Faulhaber (J.)
Neuerfundner Gebrauch eines Niderlandischen Instruments zum abmessen, etc.
Augsburg, 1610. Sm. 4to.

Hopton (A.)
Baculum geodeticum.
London, 1610. Sm. 4to.

Hulsius (L.)
Instrumenta mechanica [Planimetrum; Baculum; Circinus proportionalis].
Frankfort, 1605. 3 vols. Sm. 4to.

Flamand (C.)
La practique et usage d'arpenter, etc.
Montbéliart [1611]. 8vo.

Hopton (A.)
Speculum topographicum.
London, 1611. Sm. 4to.

Bramer (B.)
Kurtzer Bericht eines Schreg-oder Winckel-Instruments [cross staff protractor].
Marburg, 1615. Sm. 4to.

Bramer (B.)
Beschreibunge . . . eines neuen . . . . Instruments zum Grundlegung und Theylung der Circkel-Linien.
Marburg, 1616. Sm. 4to.

Rathborne (A.)
The Surveyor.
London, 1616. Fol.

Oddi (M.)
Dello Squadro.
Milan, 1625. Sm. 4to.

Faulhaber (J.)
Mathematischer Kunst-Spiegel [Perspective drawing instrument, etc.].
Ulm, 1626. Sm. 4to.

Arduser (J.)
Geometrica, etc. [on surveying].
Zurich, 1627. Sm. 4to.

Malombra (G.)
Practica . . . di misurare con la vista.
Florence, 1630. Sm. 4to.

Gunter (E.)
The description and use of the sector, crosse-staffe, etc.
London, 1636. Sm. 4to.

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Roads.

Procter (T.)
Concerning the mending of all Highways, as also for Waters and Ironworkes [second edition].
London, 1610. Sm. 4to.

Miscellaneous Inventions—English.

Bourne (William)
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The Rise and Fall of the Sussex Iron Industry.

By Rhys Jenkins.

Part I.

(Read at the Iron and Steel Institute, Westminster, on January 27th, 1921.)

Although the iron industry in Sussex has been extinct for a hundred years, the district is, historically, one of great importance, for there can be no doubt that it was there that the blast furnace was first used in England, and that it was thence that it spread to the other iron-making districts of this country.

The present paper is intended as a general survey of the Sussex iron trade. It is hoped that other papers will be laid before the Society dealing with particular aspects of that trade and with particular works, as well as with iron manufacture in other parts of the country, and generally.

At the outset it should be explained that although it has become usual to speak of the district as Sussex, it embraces parts of Kent, Surrey, and Hampshire; in fact it is the Weald between the North and South Downs. On a map, we find the sites of old ironworks extending from a little beyond Haslemere, on the West, to Sissinghurst, or say to a line drawn northwards through Winchelsea, on the East.

The manufacture of iron was carried on in the Weald, as in other parts of the country, in prehistoric times, and there are clear indications of the existence of the industry during the Roman occupation. With the coming of the Anglo-Saxons it is supposed to have sunk to small dimensions, and the indications of its existence until Norman times are very scanty. Domesday Book mentions but one iron mine in the district, but this does not necessarily mean that there was only one at work. During the 13th, 14th, and 15th centuries, the manufacture was being carried on, but probably not more extensively than in other districts, such as the Forest of Dean. In 1300 the ironmongers of London were complaining of short length in the iron bars supplied by the makers of the Weald.[1] Then about the middle of the 14th century we know that there was a forge at Tudeley, in Kent,[2] and, still later, another near Penshurst.[3]

In the early days the iron was made by a direct process, that is to say, the

[1]Stow: Survey of London.

[2]Archæologia LXIV. M. S. Giuseppi: Some Fourteenth Century Accounts of Ironworks at Tudely, Kent.

[3]Historical MSS. Com. III., 228. MSS. of Lord de L'Isle and Dudley. Books of Expenses of the Iron Forges, Henry VIII.-Elizabeth.

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ore was reduced directly into malleable iron. At the present time substantially all the iron made in the world is smelted in blast furnaces, the product of which, pig-iron, requires subsequent treatment for conversion into wrought iron or steel. It will be recognized at once that the production must have been on quite a small scale.

It was the introduction of the blast furnace that started the Wealden iron industry on its career of prosperity, that soon led to Sussex becoming the premier iron-producing district of England. Not that we must imagine that it was ever anything in the nature of a "Black Country." Although there were a great many works, they were scattered over a wide area; the product after all was very small compared with modern practice; the only fuel employed was charcoal, and power was derived from the streams, instead of, as nowadays, by burning coal in boiler furnaces.

The blast furnace had been in use on the Continent for some considerable time before it appeared in England, and here it may be explained that the term blast furnace is used to indicate a furnace of some height, fed at the open top, and from which, at the bottom, fluid metal is tapped from time to time. The date of the invention is obscure, but probably we shall not be far wrong in saying that such furnaces came into use some time in the 14th century, and somewhere in a zone comprising Western Germany and Eastern France, extending from the Alps to Belgium. The invention has been claimed for the Liége district, and it has been stated that a furnace was built near Namur in 1340, and that by the year 1400 two furnaces near Liége—Les Vennes and Grivegnée—were well known[4].

However, from quite early in the 15th century we have documentary evidence that iron founding and iron castings were known in Germany, France, and Italy. There is in existence a letter dated September 17th, 1415, from the Town Council of Strassburg to the Council of Freiburg referring to an ironfounder —isengiesser. Then it appears that the Archives Dep. de la Côté d'Or, at Dijon, contain references in 1433 to "pierres faites pour le plus gros canon de fer de fondue," and in 1400 to "un viel canon de fer de fondue"[5]. In 1460-64, we have the account by an Italian architect, Antonio Averlino Filarete, of a visit paid to a works in the Alps. He remarks that the iron from the furnace is fluid like bell-metal, and that, like it, it may be cast in moulds; and he adds that there is at the Castle of Milan a cast-iron gun in the form of a lion[6].

Other examples could be furnished, but enough has been said to show that the blast furnace was known over a fairly wide area by the middle of the 15th century.

[4]Laveleye, Baron E. de: Proc. Inst. Mech. Eng., 1883, p. 330; Journal of Iron and Steel Institute, 1913, ii., p. 14.

[5]Johannsen, Otto, in "Archiv für die Geschichte der Naturwissenschaften und der Technik," vols. 3, 5, and 8.

[6]Oettingen, Wolfgang von: A. A. Filarete's Tractät über die Baukunst. Wien, 1890.

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We have no record of the date of the introduction of the furnace into England, but it seems clear that it took place in the latter half of the 15th century. Mr. Giuseppi has published the accounts of an ironworks at Tudeley in Kent for some years about the middle of the 14th century, and these leave no doubt that a direct process was in use there at that time.[7] But when we come to the year 1492 we find that the term "ironfounder" was a recognised and apparently commonly understood expression, such as not to require explanation, clearly showing, at any rate, that iron in the fluid form was known. In the Court Rolls at Lambeth Palace for the year referred to, is to be found an entry of a payment of 67*l.* 0*s.* 2*d.* to "ye Iernefounders of Buxstede." In the following year, 1493, we have certain Chancery Proceedings on the complaint of "Pieter Roberd alias Graunt Pierre, yernefounder, dwellyng in Hertfelde" in reference to a quantity of iron amounting to over 52 tons at 3*l.* per ton, and in 1497 we find Simon Ballard at Newbridge in Ashdown Forest cast large quantities of iron shot.[8] This last entry leaves no doubt that by 1497 ironfounding was being carried on in Sussex.

The earlier entries, relating to the Buxted and Hartfield ironfounders, are not so decisive. We do not know that the term "ironfounder" was used in precisely the modern sense. The name "founder" meant a melter, and was applied for long afterwards to the man in charge of a blast furnace. Again the quantities of material concerned are quite large for the period, and it is difficult to see in what form they can have been if of cast iron, for it is to be remembered that a market for cast-iron wares had yet to be created. It would seem then that we should keep our minds open to the possibility—

(a) that the blast furnace had not yet come in, and that the ironfounders referred to were making castings by remelting cast-iron produced incidentally in the working of a direct process, or,

(b) that they were working blast furnaces and, at Buxted and Hartfield, converting the product into wrought iron, in which case "ironfounder" would be the equivalent of "founder," the man in charge of the furnace, or,

(c) that they may have been making castings from a blast furnace.

Now in view of what has been said as to the restricted field for iron castings, it is clear that furnaces would not be set up unless some process was available for converting the product into malleable iron, and we have some evidence that the finery process was known at this time. In 1496, one Robert Fyner is commissioned "to take artificers, 'founders,' and labourers for building

[7] Archæologia. Vol. LXIV., pp. 145-164.

[8] Probably Newbridge was the location of the "great waterhamor," said to have been working in Ashdown Forest in 1496. Salzmann: English Industries of the Middle Ages, pp. 30 (N.I.), 111.

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foundries for the making of iron for the ordnance "[9]. It is pretty clear that Robert Fyner was concerned in the iron trade, and it is fair to assume that he had derived his surname from his calling. However, the case is strengthened by documents of a later date. In 1544, Henry VIII. was about to make war with France, and it seemed desirable to clear up the status of the Frenchmen residing in this country. Their names were recorded, and all those who had not already received Letters of Denization were required to take the oath of allegiance and become denizens, or to leave the country. Now in the lists of denizations[10] we find a number of Frenchmen employed at various ironworks, some of whom are described as "founders," and others as "finers." The Duke of Norfolk had five or six; one of them, John Gunrie, a "finer of iron," had been in England ten years; another Maryan Predome, a "finer," had been here five years. At another works was John Lyonarde, "French born, a finer, in England thirty years," this takes us back to 1514. Another man, John Deford, aged 60, had been in England thirty-five years, i.e., since 1509, but it is not stated that he was a finer. Similarly, Lambart Symar, who had been in England since 1494, is described in general terms as an "ironmaker." Other men are mentioned as having been in this country for eighteen, twenty, and thirty years. Peter Denwall, who had been in England thirty-seven years, must have been brought over as an infant, for in 1544 his age was but forty years.

In all there are upwards of forty Frenchmen named as being concerned in the ironworks; for the most part they came from Normandy, but some are described as of Bewasyn, and others as of Picardy. One of the Picards is James Lenarde, possibly the ancestor of the well-known iron-making family at Brede. We do not find in these lists the name of Pieter Roberd or Graunt Pierre of Hartfield; no doubt he, and the original colony of iron-workers, had died before 1544.

On this evidence it seems impossible to resist the conclusion that the blast furnace, together with the finery process for converting cast iron into malleable, had been introduced into England before the year 1500, and that by that date there were at least three furnaces at work, i.e., Buxted, Hartfield, and Newbridge. Moreover, the fact that these ironworks were of French origin points to our having borrowed the new method of iron-making from France. This view is supported by the terms used in the trade—founder, finery, chafery—all of which occur in the same or in a closely similar form in the French.

No doubt the old direct method of manufacture did not disappear from Sussex at once, but survived for a time, competing with the new. However, it is likely that by the middle of the 16th century it had been displaced entirely by the blast furnace and finery. The Denization Lists mention the Duke of

[9]Calendar of Patent Rolls. Hen. VII. Dec. 13, 1496.
[10]Huguenot Society Publications, Vol. VIII.

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Norfolk's works, the King's forge at Newbridge, the forge at Parroks, Master Lunsford's ironworks, Master Wybarn's ironworks, Master Pelham's ironworks, Master May's ironworks, Master Barham's ironworks, and those of Sir William Sidney and Sir Robert Tyrwight, but these were merely the works in which were employed Frenchmen who had not already become denizens. By that date a number of native workmen had been trained in the new process, and the total number of works in the district was considerably greater. At any rate, a return made in the year 1548[11] gives the number of iron mills, furnaces, and hammers in the County of Sussex at 53. Probably we shall not be far wrong if we say that of these 26 were furnaces. In the Rape of Hastings it would seem that the development had been more particularly noticeable within the preceding seven years, while in the Rape of Lewes it had begun about the year 1533. One of the points that attract attention in this return is that the newer works were being established as near as possible to the sea coast. In many instances we find stated the number of miles the works is distant from the salt water, as, "the iron mill of Robertsbridge standing within 3 miles of the salt water," and "the iron hammer of Mountfield within 4 miles of the salt water." Clearly the object was to reduce as far as possible the expensive land transport. Every reduction in the cost of carriage placed the Sussex maker on a more favourable footing, as against the foreigner, in the London market. But quite apart from this there seems at this period to have been a slackening in the foreign competition which assisted the growth of the industry. In the return of 1548 before alluded to, the people of Hastings say that in spite of the increased number of furnaces, the price of iron had gone up from 4*l.* to 9*l.* and 10*l.* a ton.

This growth was based almost entirely upon the production of wrought iron. Apart from a few open-sand castings, such as firebacks, the only cast iron goods made were iron "gunstones" and pellets, and for these the demand was limited and irregular. It is an interesting question how the cannon balls were moulded. Biringuccio states that in Italy in 1495 they were cast in metal moulds. Possibly this plan was adopted in Sussex.

The names of the owners of works mentioned in the Denization Lists point to the change that was in progress in the organisation of the industry. With the direct process the make was necessarily on a small scale, resulting in the production of a bloom weighing from 100 to 200 pounds at a time. The manufacture could be carried on with a few appliances, inexpensive erections, and entirely by human labour. It required but small capital outlay—it was the industry of the small man. The coming of the blast furnace rapidly changed all that. The furnace, with the finery, chafery and hammer were comparatively expensive structures. The furnace bellows and the hammer called for more power than could be applied conveniently by human power, so that water power

[11] Hatfield MSS. (Hist. MSS. Com.), Vol. XII., p. 19.

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had to be resorted to. This meant the acquisition of an existing mill, possibly of a number of water rights, the construction of dams or bays to form the furnace and hammer ponds, once so common a feature in Sussex. All this required the outlay of capital, probably in many cases the ownership of land. In short, we see iron-making being transformed from a craft such as that of the blacksmith into something approaching modern capitalistic production.

In coming on to the date 1548 we have passed a great landmark in the history of the Sussex Iron Industry—the founding of the first cast-iron gun—that is to say, in England, for iron guns had been cast long before on the Continent. This took place in 1543 at Buxted. The makers were Ralph Hogge and Peter Bawde. Hogge was the owner of the furnace, and Bawde was one of the founders of bronze guns in the service of the King. The reason he was brought down to Sussex is clear enough. Hogge knew how to work a furnace and could furnish the molten iron; he knew nothing about guns or the preparation of the moulds for gun-founding. Bawde, on the other hand, was an expert gun-founder in bronze and was learned in the proportions of the various pieces. We do not know that he adopted the same proportions, for instance in regard to the thickness of metal, or exactly the same methods of moulding, but in any case, the cast-iron guns were a success. As compared with bronze guns there was an enormous advantage in cost, even after the founder had made a good profit and paid the carriage to London. We do not hear that Bawde continued to be concerned with iron guns, possibly some of his assistants were left to carry on the work, but at any rate, the production went on steadily, and in 1557 we have a letter, from an Italian in London to the Duke of Mantua, remarking upon the cast-iron guns at the Tower. The writer finds it necessary to explain that they were made in the same way as the bronze, so presumably, although cast-iron guns had been made long before, they had not come into general use on the Continent.[12]

One of the furnaces at which the founding of guns was taken up was that at Worth, and here again Mr. Giuseppi has laid us under an obligation.[13] He has published the accounts of these works for a period near the middle of the 16th century, and they are remarkably full in details of cost. There is also an inventory of the Worth establishment, from which it appears that it had "a duble ffurnace to cast ordynaunce, shotte or rawe yron wt. all implements and necessaries apperteynin to the same." There was also a finery for the production of wrought iron.

[12]Cal. State Papers: Venice. Vol. VI., pt. 3, p. 168. "There is a quantity of artillery in the Tower and also outside on the banks of the river; I counted them roughly, and estimated about 250 brass pieces, and 600 of iron, some of which are cast like those of brass." Annibale Litolfi to the Duke of Mantua, &c. London, June 20, 1557.

[13]The Archæological Journal, 2nd S., Vol. XIX. (1912), pp. 276-311. The accounts of the Ironworks at Sheffield and Worth, in Sussex, 1546-1549.

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In the period covered by the accounts, December 24, 1546, to January 17, 1549, the amount of wrought iron made was 156 tons, and 56 tons of guns of various kinds and 52 tons of shot were cast. The guns were valued at £10 a ton, the shot at about £4. The only other castings made were four chimney backs, sold at 3s. 4d. each. The shot-founders were paid at the rate of 10s. a ton, and the gun-founders £5 a ton, "bering al charges except metall." The furnaces of these days were quite small; allowing that to produce 156 tons of wrought iron, 234 tons of pig iron were required, we have with the guns and shot a total of 342 tons produced in a period of 107 weeks—that is, 166 tons per year. It is stated that the work was done in 88 foundays, the founday was a period of six working days, so that we have a cast of a little under 13 cwt. per day, and this from a double furnace, that is to say, two furnaces built on the same block. One is inclined to think there may be something wrong in the figures, for guns up to between 2 and 3 tons weight were being cast. There is some indication, however, that the gun-founders contrived to retain the molten metal in the hearth of the furnace and not to tap for a couple of days until a sufficient quantity had accumulated. It appears that the furnaces in Hainault at about this date were of approximately the same capacity, say, 6 cwt. in 24 hours,[14] and an undated paper, ascribed to the reign of Henry VIII., relating to "the yron mylles called Newebridge in the nether ende of the Forest of Ashdowne," estimates that "this myll will make yerely if she be well stored and applied, 80 tonne at least."[15] This figure is for the wrought iron product; the pig-iron required would be 120 tons, and with 40 foundays of six days each, we have a daily production of 10 cwt.

The manufacture of cast guns soon became a prominent feature in the Sussex trade, and it is of this branch that we have most information. It seems to have been the first manufacturing industry in which the English distinguished themselves. During the reign of Elizabeth and onwards to the time of Charles II., the English cast-iron guns were in demand all over the Continent. The historian, Hume, noticed this fact, and remarked: "Shipbuilding and the founding of iron cannon were the sole (arts) in which the English excelled. They seem, indeed, to have possessed alone the secret of the latter, and great complaints were made every parliament against the exportation of English ordnance."[16]

The particular reason why we excelled in the production of cast-iron guns is not clear. No doubt the Sussex iron was a good foundry iron, but such was to be found in a good many places on the Continent. Possibly there had been some development in the construction and working of the furnace; it would seem that the double furnace such as has been referred to in connection with the

[14] Laveleye: Journal Iron and Steel Inst., 1913, ii., pp. 8-31.
[15] Exchequer T.B. Forest Proceedings, No .197. Henry VIII.
[16] Hume: History of England; Appendix to the reign of James I.

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Worth ironworks may have been an English invention. Swedenborg states that cannon founding was established in Périgord by the aid of workmen brought over from England, and that some of the furnaces there were double, i.e., two furnaces built on the same block, in order to procure enough metal to cast large guns.[17]

But the most likely explanation is that the Sussex men had invented some better and cheaper mode of making the moulds than that which had been in use by the founders of bronze guns; for not only were the guns better, but they were also cheaper than the foreign guns. Of the attempts made to induce the Sussex workmen to go abroad there is ample evidence in the Register of the Privy Council.[18]

It is necessary, however, to guard against the idea that the production of guns became at any period the largest item of production of the Sussex works. It was, no doubt, the most profitable, the foreign demand in the reign of Elizabeth, for instance, was very considerable, but all the iron-makers who may have wished to enter upon this branch of the trade could not do so simply because the workmen capable of making the moulds were few in number and the training of new men took time; and then later on came Government measures in restraint of the manufacture of guns for export.

By the reign of Charles II. these restrictive measures had so enhanced the price of guns on the Continent as to make the trade a very enticing one, and foreign competition made itself felt. Sweden in particular became a large producer. The Wealden gun-founding industry dwindled away to nothing. However, by that time, a demand was springing up for other cast-iron goods, pots, pans and the like. It would seem that apart from such things as could be produced by open-sand casting, the articles made were of circular section, probably the moulds were, like those for the guns, struck up in loam. However, the matter of the production of guns and other castings in the Weald cannot be entered into here.

In the year 1548 it was stated that there were 53 ironworks in the county of Sussex, and of these we have assumed that 26 were furnaces. No figures are available in regard to the extent of the industry for the ensuing quarter of the century. The enquiry of 1548 arose from the public outcry against the consumption of wood by the ironworks. This outcry persisted, and in Parliament repeated objections were raised against the works both on this ground and on the impolicy of exporting ordnance. Ralph Hogge, the Queen's "gonnestone maker of yron," had obtained, in 1568, a patent giving him the sole right to export iron ordnance and shot. In January, 1574, he complained of the infringement of the patent.

[17]Swedenborg: De Ferro. 1734. p. 145.

[18]Register of the Privy Council, 1624-1627. Vols. 32-36.

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It appears that at this time there were seven founders casting ordnance, and that the total output was 400 tons a year. Four of these founders had begun to cast ordnance only within the preceding five or six years, Hogge himself, who it seems had two furnaces, and two others had been in the trade a long time.

Possibly each of these complaints contributed to cause the enquiry made in 1574 as to the number and ownership of the works in the Weald. The Commissioner gives long lists of the owners or founders and of the corresponding furnaces and forges, but apparently they are not exhaustive, for he says that in all there were " not so few " as a hundred furnaces and iron mills, and his list falls considerably short of this number. It may be that the lists name the important works, and that he made a guess as to the total.

In 1588 we have a list of 37 owners, 23 furnaces and 32 forges. Norden, in 1607, states that there were near 140 hammers and forges in Sussex; this can only have been a rough estimate, and almost certainly is too high. In 1619, of the founders in the Weald, 5 were casting guns.

Coming on to the time of the Commonwealth, we have a most interesting document giving the names of all the furnaces and forges in Sussex, Kent and Surrey in the year 1653[19]. In all 35 furnaces and 45 forges are mentioned. Of these, 27 furnaces and 42 forges were in Sussex; 7 furnaces and 1 forge in Kent, and 1 furnace and 2 forges in Surrey.

We have now come to what appears to have been the culminating point of the iron trade of the Weald, and, as the paper had already reached a considerable length—in spite of efforts at condensation—the consideration of the progress of the industry in later years must be reserved for another occasion.

[19] Sussex Archæological Collections. Vol. 32, p. 19 (1882). J. L. Parsons: The Sussex Iron Works.

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The Rise and Fall of the Sussex Iron Industry.

By Rhys Jenkins.

Part II.

(Read at the Iron and Steel Institute, Westminster, on May 13th, 1921.)

In the first part of this paper the progress of the Sussex iron industry was traced down to the time of the Commonwealth, to the year 1653. In the present and concluding portion the story will be continued to the extinction of the industry early in the 19th century. Consideration will also be given to the technical aspect of the subject, although one is precluded from going to any great length in that direction by the fact that the historical material available is very scanty.

To take the technical aspect first, a few words must be said about the iron ore. The ore is an argillaceous ironstone found in the Wealden clay. The area with which we are concerned—except as to its eastern end—is bounded by the North and South Downs, which converge in the chalk mass of Hampshire. Underlying the chalk, and in the order named, we find the upper greensand, the gault, the lower greensand, and the Wealden beds, made up of the Wealden clay and the Hastings beds. The Hastings beds form the high ground constituting the cliffs at Hastings and extend inland to Tunbridge Wells and then westwards, including Crowborough Beacon and Ashdown Forest. They are described as consisting for the most part of sands, with subordinate beds of clay, and have been subdivided into three beds—Tunbridge Wells sands, Wadhurst clay and Ashdown sands. The lower greensand, the Wealden clay and the Hastings beds have all been worked for iron, but the main source of supply was in the Wadhurst clay of the Hastings beds. Topley, "Geology of the Weald," 1875, states that—

> The ore most commonly used was the clay ironstone, which occurs in nodules and thin beds towards the bottom of the Wadhurst clay. There is also a bed of shelly calcareous ironstone occurring a few feet above the Ashdown sand, which would of itself serve for both ore and flux. It was probably extracted at the same time as the ironstone.
>
> The ore was worked mainly by means of bell-pits, of about six feet in diameter at the top, and widening towards the bottom. They were generally shallow, rarely more than twenty feet deep: sometimes they were connected by levels. Great numbers of these pits ("mine pits") still remain in the woods; generally they are full of water. On the pasture fields they have been partly filled up, and here the surface very much resembles that produced by "day-falls" near the crop of a worked-out coal seam. Scarcely any trace of workings now remain over the arable lands. Waste heaps do not occur over the worked ground.

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The beds have been worked from Roman times onward, as remains in the cinder heaps testify. During the blast-furnace period, John Ray's account, referred to later on, makes it clear that different sorts of ores were mined and mixed together for smelting. He does not mention the use of a flux, so probably one of the sorts carried the flux with it.

Arthur Young, describing the workings at Ashburnham in 1792, mentions quite a number of beds of ironstone as being worked there, also a thin bed of limestone that was utilised for a flux.[1] The percentage of iron in the clay ironstone was about 35.

It is somewhat remarkable how few relics remain of the appliances and plant of this once important industry, and how little trace it has left in local tradition. It may be that as the trade declined the workmen with their families migrated to other iron-making districts. There are hammer and furnace ponds, or traces of them in various parts of the district—the pond at Horsmonden is a very fine one—and there is a number of place-names indicating sites where the industry was carried on. Lower gives a drawing of a hammer post existing *in situ* in his time in the parish of Buxted,[2] and an old hammer-head and anvil that had been found on the site of a works near Etchingham was illustrated in one of the engineering journals some years ago.[3]

Pictorial representations of early British ironmaking generally are few in number. So far as is known to the writer, there are but three concerned with the Wealden industry. First, we have the cast iron fire-back of Richard Lenard, of Brede furnace (pl. i). A number of these of different sizes, but of substantially the same design, were cast during the 17th century. The design comprises a representation of the ironmaster himself with his dog, and a furnace with some of the tools and appliances used in connection with it. Next, we have a clock, formerly in the possession of the late Mr. Charles Dawson, of Lewes (pl. ii). This clock was made, probably, in the 18th century, and its brass dial—here reproduced[4] from a photograph—bears the name "Beeching, Ashburnham," and has engraved upon it a representation of the whole process of iron making; the cutting of the wood and its conversion into charcoal, the digging of the mine, the furnace with the water-wheel for its bellows, and the mill pond, the finery and hammer, and some of the products of the furnace—guns and shot. To make the detail clearer, a drawing of the clock face by Mr. W. A. Young is reproduced in Plate iii.

Thirdly, in Swedenborg's work on iron we find a rough drawing of the

[1] "The Victoria County History of Sussex" quotes the list in full at page 241, Vol. II.

[2] "Lower, M.A., Contributions to Literature," 1854; also in "Sussex Archæological Collections," Vol. II.

[3] THE ENGINEER, January 3rd, 1902.

[4] From Hayden's "Chats on Cottage and Farmhouse Furniture," by permission of the publisher, T. Fisher Unwin.

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Gloucester furnace at Lamberhurst, from a sketch made early in the 18th century. This is reproduced (pl. iv), not that it is of technical value, for it is obviously altogether out of scale, and does not distinguish between the inside and the outside of the furnace, but because it is the only drawing we have of a Wealden furnace.

In the matter of descriptions of the process of ironmaking as carried on in Sussex, we have the account already alluded to given by John Ray in his "English Words Not Generally Used," 1674. Ray tells us: "This account of the whole process of the Iron-works I had from one of the chief Iron-masters in Sussex, my honoured friend *Walter Burrell* of *Cuckfield* Esquire, deceased," and it is worthy of careful consideration. It is given below in full, and to illustrate it drawings have been taken from the *Encyclopédie* of Diderot and D'Alembert,[5] which although they show French practice at nearly a century later, probably agree in the main with Sussex practice in Ray's time.

THE MANNER OF THE IRON-WORK AT THE FURNACE.

The iron-mine lies sometimes deeper, sometimes shallower in the earth, from 4 foot to 40 and upward.

There are several sorts of mine, some hard, some gentle, some rich, some courser. The iron-masters always mix different sorts of mine together, otherwise they will not melt to advantage.

When the mine is brought in, they take small cole [charcoal] and lay a row of small cole, and upon that a row of mine, and so alternately S.S.S., one above another, and setting the coles on fire, therewith burn the mine.

The use of this burning is to mollifie it, that so it may be broke in small pieces; otherwise if it should be put into the furnace as it comes out of the earth, it would not melt, but come away whole.

Care also must be taken that it be not too much burned, for then it will loop, *i.e.*, melt and run together in a mass. After it is burnt, they beat it into small pieces with an iron sledge, and then put it into the furnace (which is before charged with coles), casting it upon the top of the coles, where it melts and falls into the hearth, in the space of about twelve hours, more or less, and then it runs into a sow. The hearth or bottome of the furnace is made of a sandstone, and the sides round to the height of a yard, or thereabout: the rest of the furnace is lined up to the top with brick.

When they begin upon a new furnace, they put fire for a day or two before they begin to blow.

Then they blow gently and increase by degrees till they come to the height in ten weeks or more.

Every six days they call a *Founday*, in which space they make 8 tun of iron, if you divide the whole summ of iron made by the foundays; for at first they make less in a founday, at last more.

The hearth by the force of the fire, continually blown, grows wider and wider, so that if at first it contains so much as well make a sow of 600 or 700 pound weight; at last it will contain as much as will make a sow of 2000 *l*. The lesser pieces, of one thousand pounds or under, they call *Pigs*.

Of 24 loads of coals, they expect 8 tun of sows: to every load of coals, which consists of 11 quarters, they put a load of mine, which contains 18 bushels.

A hearth ordinarily, if made of good stone, will last 40 foundays, that is 40 weeks, during which time the fire is never let go out. They never blow twice upon one hearth, though they go upon it not above five or six foundays.

The cinder, like scum, swims upon the melted metal in the hearth, and is let out once or twice before a sow is cast.

[5] Vol. 7, Art. "Forges." The volume of text is dated 1757, the corresponding volume of plates, 1765.

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THE MANNER OF WORKING THE IRON AT THE FORGE OR HAMMER.

In every forge or hammer there are two fires at least; the one they call the *Finery*, the other the *Chafery*.

At the finery, by the working of the hammer, they bring into *blooms* and *anconies*, thus:

The sow they at first roll into the fire, and melt off a piece of about three-fourths of a hundred-weight, which, so soon as it is broken off, is called a *loop*.

This loop they take out with their shingling tongs, and beat it with iron sledges upon an iron plate near the fire, that so it may not fall in pieces, but be in a capacity to be carried under the hammer. Under which they then removing it, and drawing a little water, beat it with the hammer very gently which forces cinder and dross out of the matter; afterwards by degrees, drawing more water, they beat it thicker and stronger till they bring it to a *bloom*, which is a four-square mass of about two foot long. This operation they call *shingling the loop*.

This done, they immediately return it to the *finery* again and after two or three heats and working, they bring it to an *ancony*, the figure whereof is, in the middle, a bar about 3 feet long of that shape they intend the whole barr to be made of it; at both ends a square piece left rough to be wrought at the *chafery*.

NOTE.—At the finery 3 load of the biggest coals go to make one tun of iron.

At the chafery they only draw out the 2 ends suitable to what was drawn out at the finery in the middle and so finish the barr.

NOTE.—1. One load of the smaller coals will draw out one tun or iron at the chafery.

2. They expect that one man and a boy at the finery should make 2 tuns of iron in a week: two men at the chafery should take up, . ., make or work, five or six tun in a week.

3. If into the hearth where they work the iron-sowes (whether in the chafery or the finery) you cast upon the iron a piece of brass, it will hinder the metal from working, causing it to spatter about, so that it cannot be brought into a solid piece.

The roasting or calcining of the ore, as described by Ray, was done in heaps in the open air; at a later date there is reason for thinking that kilns were used. The estimate for the output of the furnace, 8 tons per founday of six days, seems to be too high, for this period at any rate. Assuming there were forty foundays in a year, we get an annual output of 320 tons; it is doubtful whether at any period any furnace in Sussex did much more than half this quantity. The Gloucester furnace no doubt did more than that, but this was the biggest furnace in England at that time; it had been built in 1695. The furnaces were square truncated pyramids having walls of considerable thickness; possibly the best in Sussex in Ray's time was about 22ft. square at the base. This was the size of some furnaces in the Forest of Dean erected apparently about 1611, and representing probably the best practice of the day. Inside they were approximately of egg shape, terminating at the bottom in a rectangular hearth of considerable depth.

Turning now to the French drawings (pl. v) shows the outside of the furnace and casting-house. It will be observed that there is a house and chimney above the furnace; the writer is not aware whether such houses were erected above the Sussex furnaces, they are not shown on Lenard's fire-back (pl. 1) nor on the clock face (pls. ii and iii), but their absence from these representations is not conclusive; they appear to have been used in the Forest of Dean in 1635, and known as bridge houses[6]. The man at the furnace mouth is trying with a gauge the depth to which the material has fallen to ascertain whether it is time for another

[6] "A Survey of the Forest of Dean Iron Works in 1635," given in H. G. Nicholls "Iron-making in the Olden Times."

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charge. At *i* are shown balance weights fixed on the ends of levers *e* for pulling up the bellows. Plate vi shows the inside of the casting-house and the founder and his assistant at work preparing the mould for the sow; at F is shown the slag running out from the furnace, where it floats on the molten iron; and at R R R the bellows worked by cams on the shaft of a water-wheel. The bellows here shown consist of two wooden boxes, pivoted together and telescoping one over the other. A similar construction is described in Plot's *Staffordshire*, 1686, but those used in Sussex were of the ordinary country smith's type; necessarily, they were of large dimensions. In the Forest of Dean in 1635 the bellows boards measured 18ft. by 4ft. Before leaving the furnace we may turn to Swedenborg's sketch (pl. iv). The Gloucester furnace was 28ft. high, and it is stated that it was 4ft. higher than any other in England at that time, 1724. The greatest size inside was 7½ft. by 8ft. For cannon the hearth was made 5ft. long and 21in. wide; for ordinary work, 4ft. long and 18in. wide. The sloping parts E are described as the "boshes," and the tapping place is shown at H.

The chafery was merely a re-heating furnace; the conversion of the cast iron into malleable was effected in the finery. Ray gives a somewhat incorrect impression in saying that a piece of about three-fourths of a hundredweight is melted or broken off the sow. The end of the sow was exposed to the fire and melted away gradually, the sow being pushed forward to keep its end in the same position. The molten material dropped into the hearth, where it assumed a pasty condition and was worked up into a mass—the loop—by the finer. The *Encyclopèdie* drawings relate to a somewhat different arrangement to that employed in England, in that a single furnace was used instead of a separate finery and chafery. The operations were the same, but they were conducted with one fire instead of two. This practice was apparently of recent introduction in France. It had been used earlier in Germany, and was considered to be far more economical in fuel than the use of separate fineries and chaferies. Plates vii, viii, ix, and x all show the same forge at different steps of the operations and from different points of view. In plate vii the workman marked Fig. 1 is advancing the sow over rollers into the fire. Fig. 2 is the finer, working up the mass of iron in the hearth into the renard —in this process the furnace was called a renardière and the loop a renard. Fig. 3 is consolidating the renard as it has come from the fire, in a condition something like a sponge, by beating it with a sledge on the iron plate *p*. In this operation a lot of the dross is removed. In plate viii the finer, Fig. 1, is at work on the hearth, the hammerman, Fig. 3, is shingling the renard, and in this operation we are told that the slag escapes like water from a sponge. The hammerman's assistant, called the "Gougat," Fig. 2, is regulating the supply of water to the wheel that works the hammer, to start and stop working and to control the strength of the blows. In the next drawing (pl. ix) we have the forging of the ancony, and a reference to

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the inscription at the foot of the drawing serves to solve an etymological puzzle—it is clear that our "ancony" is the same word as the French "encrenée."

Plate x shows the next step in the process, one of the large ends of the ancony being drawn out to the size of the finished bar. Here the French term for the operation is "parer la maquette." Ray does not use a word corresponding to "maquette," but such a word was in use in this country. Plot—*Staffordshire*, 1686—uses the expression "mocket head." The finer, Fig. 1, is engaged in tapping out the slag from the hearth, and the assistant hammerman in throwing water on the anvil and hammer. The bar B in plate viii is the maquette of plate x, with its large end being heated in the fire preparatory to drawing it out to the finished size. These drawings make the construction and mode of actuation of the hammer pretty clear. The hammer is pivoted between uprights 1, 2, the upper ends of which embrace a beam *δ*, called the 'drosme[7]; " the overhanging beam 13 above the hammer is a spring beam. The bellows 8, 9 (pl. vii) are worked by cams on the shaft *f* of a water-wheel; they are coupled together by a balance beam D*d*, suspended from a spring beam F.

We must now revert to the economic aspect of our subject. It is not known precisely when the Wealden iron industry reached its highest point. There are no figures as to the total quantity made, no certain statistics of the number of furnaces until late in the history of the industry, and even if we had the number of furnaces from year to year we should still be on uncertain ground, for we must not assume that the make per furnace was uniform, or that it remained constant. The natural tendency would be towards an increase in the size, and hence in the product of the furnaces, so that even with a diminished number at work, the total product might be greater. On the other hand, we have to consider the power available for working the bellows. Increased capacity and height of the furnace would necessitate increase in the volume and pressure of the air supplied to it, and this would demand more power. Now, possibly in the majority of cases the full extent of the fall of water available at any given works may have been utilised at a comparatively early date, so that furnaces of larger size could not be used. Probably we shall not be far wrong if we say that the industry began to decline during the period of the Commonwealth. The document[8] referred to at the end of Part I. of this paper gave the total number of furnaces in the Weald in 1653 as 35. It gives also the corresponding numbers for the years 1664-7. Of the twenty-seven Sussex furnaces, but eleven were now at work, nine others were in condition to be worked if required, and seven were derelict. Of the seven Kent furnaces, one only is stated to be ruined, but it is not stated that the others were at work; and the one furnace in Surrey was not working. The forty-two forges in Sussex had been reduced to eighteen in 1667.

[7]In the Forest of Dean Survey of 1635 we find the term "drome beams."
[8]"Sussex Archæological Collections," Vol. 32, page 19.

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Pursuing this matter of the number of furnaces, we find from Budgen's map of Sussex that by 1720 the number of furnaces in the county had fallen to twelve and that of the forges to seven. One judges this map to be fairly accurate, for we have a list of forges for about the same date which gives the same total.[9]

By the year 1740 the number of furnaces in the Weald had sunk to fifteen; of these there were four in Kent, one in Hampshire, ten in Sussex, but not one in Surrey. Forty years later, 1780, there was but one furnace at work in Kent—the Gloucester furnace at Lamberhurst—and by 1788 that had ceased working, and the number at work in Sussex had fallen to two. These were Fernhurst in West Sussex, and Ashburnham or Penhurst. In 1796 this last was the only furnace at work in the Wealden area.

The inquiry naturally arises: To what cause is this decay to be attributed? At first sight one is inclined to say that it was due to the introduction of mineral fuel for smelting. The competition of coal no doubt had some bearing upon the final extinction of the industry, as it had with the charcoal iron manufacture in other districts, but a little consideration will show that the Wealden iron trade had sunk to small dimensions before coke had become a serious competitor with charcoal in iron making.

Although attempts had been made by Dud Dudley and others to smelt iron with pit coal, it was not until 1735 that the problem was solved by Abraham Darby II. at Coalbrookdale. The new plan did not spread very rapidly at first, and it is quite safe to say that it was not until after 1750 that the coke furnace became a serious rival of the charcoal furnace.

Now, we have seen that the number of furnaces in the Weald fell from twenty-five in 1664 to fifteen in 1740, and that the trade was already well on the down grade. Obviously, this was not due to the competition of coke iron.

In 1740 there were in England and Wales fifty-nine furnaces, and the total make was 17,350 tons.. In the Weald there were fifteen furnaces, giving a total make of 2,000 tons. The average production per furnace for the whole country was 294 tons, while the average for the Weald furnaces was 133 tons. The Weald had one-fourth of the number of furnaces, but only one-ninth of the production.[10]

In 1788 the *charcoal* furnaces in England and Wales numbered twenty-four, and they produced 13,100 tons, an average of 545 tons per furnace, *i.e.*, the production per furnace was twice as great as it had been in 1740. On the other hand, the two furnaces now at work in the Weald produced in this year 300 tons, which represents but a very small increase on the average for the Weald in 1740, and no doubt such small increase as there is shown was not due to an increased output at these furnaces, but that they were bigger or of better design than those that had

[9] "The Interest of Great Britain in Supplying herself with Iron Impartially Considered," *ca.* 1725.

[10] The figures are taken from Scrivenor, "History of the Iron Trade," 1841.

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ceased working. The Weald now had one-twelfth the number of charcoal furnaces and showed but one-forty-fourth of the make. Although there was a very considerable importation of foreign iron, we see that the production in England and Wales had increased very considerably, that the charcoal furnaces in other districts had attained far bigger outputs, while in Sussex the output remained unchanged and the number of furnaces had fallen very much.

One is forced, then, to the conclusion that the reasons for the decay must be sought elsewhere than in the competition of mineral fuel. The final cause, it is needless to say, was that the ironmasters could not make iron at a profit, and this may have been due to several factors acting together. Failure in the supply of fuel can hardly have been one of these factors. Although there had been great outcries against the consumption of wood by the ironworks, Defoe, in 1724, remarks on the abundance of timber in the district, " the three counties of Kent, Sussex and Hampshire being an inexhaustible storehouse of timber, never to be destroyed but by a general conflagration."

Lack of enterprise on the part of the ironmasters may have had some bearing upon the matter. Before the decay set in many of these would have become wealthy men, indisposed to launch out into new and larger projects. But this is not an adequate explanation of the decay of the trade over the whole area, particularly as we know that new furnaces were put up. Lamberhurst—Gloucester—furnace was set up in 1695, and was said to have been the biggest in the country at that time. Darvall furnace was " lately built in 1694, when it was offered for sale with the manor of Mountfield "[11]; and in Budgen's map of 1724 two of the furnaces are marked " new furnace." One of these is Heathfield, which was working up to 1787.[12]

Possibly an explanation why, with the development of the iron manufacture in Staffordshire and the northern and western counties, that of Sussex fell off may be found in the question of power for working the bellows and hammers. Water power was employed for this purpose all over the country, but compared, say, to Shropshire, the Weald was in a far inferior position, both in regard to rainfall and to the head of water that could be utilised. This inferiority acted against the Sussex ironmaster in two ways—it increased the proportion of the year during which the works were forced to stand idle from the absence of water, and it prevented an increase in the size of the bellows, and so of the furnaces.

Again, foreign competition possibly was more acutely felt by the ironmakers of South-Eastern England than by those of other districts. Setting aside

[11] *London Gazette*, November 26th-29th, 1694.

[12] Lucas, P. Heathfield, " Memorials," 1910. The Heathfield furnace accounts, in 1740, mentions a " Boreing Wheel," . . ., a water wheel for driving a boring mill. This is the only one that the writer recalls to have seen referred to in connection with Sussex works. It appears that guns were cast at Heathfield up to 1775.

N.B.—Blocks for the plates IV. to X. inclusive have been kindly lent by the Editor of " The Engineer."

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a small local demand for agricultural and domestic purposes, their production would go to supply the London market. Even if it got water transport from Chichester, Lewes, Rye or the Medway River, there would still be a greater or less length of land carriage from the works to the shipping place, and the roads of Sussex were notoriously bad, so that cartage might become a serious item in the cost. In London the Sussex ironmasters would find the men of Sweden, Spain, France and Germany competing against them, and certainly in respect of Sweden and Spain with a superior iron. The competition of Sweden by the end of the 17th century had become a very serious matter; that of Spain, however, had become less important.

No doubt the cost of labour was, at any rate generally, in favour of the Continental maker. The English workman demanded a far more generous diet than his foreign rival managed to subsist upon. Defoe, writing in the early part of the 18th century, contrasts the French workman living "on an onion and a draught of water, and a bunch of grapes, and a piece of bread," with the Englishman who had his beef and pudding.

Before concluding, a few words should be said as to the Ashburnham works. In 1796 Ashburnham, or Penhurst, furnace was the only one at work in the Weald. There are discrepancies in the various accounts as to the date when it ceased working. It seems clear that Ashburnham forge continued at work for some years after the furnace was stopped, and this may have caused some confusion. Probably we shall be very near the mark if we say that the furnace ceased work about 1810 and the forge about 1820. Lady Dorothy Nevill—"Under Five Reigns"—has a curious little story about the stoppage of the furnace. She writes: "Ashburnham was closed in 1809, the immediate cause of it being the failure of the foundrymen, through intoxication, to mix chalk with the ore, by reason of which it ceased to flow, and the blasting finally ended."

With this anecdote we conclude a chapter in the history of one of the most important industries of these islands, and one that has in it even a touch of romance.

The paper was illustrated by an ordnance map of the Weald on which the Author had indicated by pins the sites of ironworks, by an aquatint of the Coalbrookdale Ironworks in the 18th century, and by a relief model of the Weald, kindly lent by the Director of the Science Museum, South Kensington.

The discussion on the two parts of the paper was taken part in by Mr. Hall, Mr Graves, Mr. Mark Robinson, Dr. Lones, Mr Dendy Marshall, Sir George Greenhill, Mr. Lionel Robinson, Mr. Birkett, the Hon. Secretary, Mr. Lloyd, of the Iron and Steel Institute, who showed books from the Library, Mr. W. A. Young, who showed an interesting collection of photographs of fire-backs, etc., of Sussex iron, Mr. Legros, Mr. Lyon Thomson, and Mr. Walters.

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The Mystery of Trevithick's London Locomotives.

By Loughnan St. L. Pendred.

(*Read at Marconi House, Strand, W.C., on March* 2, 1921.)

Before Francis Trevithick published, in 1872, the "Life" of his father, the world knew but little of the "Cornish Giant." You may search all the magazines, encyclopædias, and books on the steam engine issued during the first fifty years of the 19th century and find no more facts about Richard Trevithick and his work than would fill a column of *The Times*. Of the biographies that preceded Francis Trevithick's "Life," Hyde Clarke's, published in 1849, is the most important, but it is no more than a pamphlet,. Francis devoted extraordinary pains to his task. He collected a great deal of matter—much of it is very valuable—but he presented it in a way that is the despair of the reader. The book occupies two stoutish volumes—frequently bound in one—and without exaggeration it may be said that had the author adopted the suggestion of Woodcroft and submitted it to the revision of a competent editor, it could have been reduced without material loss to half its bulk. He rejected that course because, as he wrote, "steam engine literature does not stand very high in my poor estimation," and "I think our written history of the steam engine a disgrace on humanity. I hope my work will not increase it."

As a consequence the book is made tedious by repetition; for nearly every letter and document in it is paraphrased. Yet with all his faults we owe to Francis Trevithick the better part of our knowledge of the life and work of one of the greatest engineers the world has ever known, and we can forgive him for the trouble he puts us to for the real value of the material he presents.

Fortunately, we are concerned this evening with only a very small portion of the "Life." We have to give attention to little more than the three chapters in Vol. I., which deal with "Locomotion"—Nos. VII., VIII. and IX. In these chapters may be found all that is known—and a great deal that is only guessed—about Trevithick's two London locomotives—the road engine of 1803 and the railway engine Catch-me-who-Can of 1808. An attempt will be made in this paper to show that, as a matter of fact, little or nothing is known with precision about either engine. They are both shrouded in a mystery which it is hoped this Society may some day be able to dispel.

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The first and most baffling fact that confronts us is that contemporary literature is almost silent about both machines. According to the accounts given by Francis—collected, be it noted, many years after the events and, in consequence, from old men—the steam coach made several trips athwart London, taking Oxford Street and Tottenham Court Road in its career; according to Mrs. Humblestone—1860—all the traffic in the first-named thoroughfare was stopped. The shops were closed during its passage, and Hyde Clarke asserts that "crowds scrambled to the roofs of the buildings," and "busmen and cab-drivers" pelted the engine with "cabbage stalks and rotten eggs." No Londoner had ever seen anything of the kind before, and in the whole world, with the exception of those who had witnessed the brief trials of Cugnot's lorry, only a handful of people in Cornwall had ever beheld a self-moving vehicle. In such circumstances is it not extraordinary that the news sheets and journals of the day took no notice of it, and that in the many books on the steam engine which soon issued from the press the first real steam carriage in the world is never mentioned? So incredible it is that an event of such moment could have passed with so little notice that the hope may be expressed that some day references to it will be found. All those, it is suggested, who have access to old letters, diaries, note books and scrap albums written or compiled in London towards the end of the year 1803 should examine them with care.

It may be said that the mystery which surrounds the steam coach is in some measure accounted for by the early hours at which the coach seems to have made its trips, and by the route it took. That argument cannot be advanced in the case of the locomotive Catch-me-who-Can. For that engine, an enclosure, said to have been some hundred or more feet in diameter, was erected in the fields where now stands Euston Square. On a circular railway within that enclosure Trevithick drove his "steam horse" and hauled after it a carriage full of people. Moreover, a sporting element was introduced into the event by the report that the engine was backed against a racehorse. This enclosure thousands of persons are said to have entered on payment of a shilling. A picture of it, engraved by W. J. Welch, appears in the "Life" (vol. 1, p. 194). Again, it seems incredible that contemporary evidence on so great a novelty should be of the meagrest, and that even approximately contemporary evidence should be weak and contradictory, as will presently be shown. We are faced with the extraordinary fact that an engine which, from an alleged portrait, has excited the admiration of engineers for the last fifty years was practically unknown to those of its day and is unrecorded in the early histories of the steam engine. Surely it may justly be said that here is a mystery!

Pains have been taken to examine anew possible sources of information about these two engines, but it must be admitted that Francis Trevithick had to

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all intents and purposes left no stone unturned in his search for facts, and very little, indeed, that is not recorded in his pages has been found. We are, therefore, in seeking for the truth about these two famous productions able to do little more than examine critically the statements presented by Francis. It must at once be admitted that when this plan is followed the mystery to which we have alluded is deepened rather than removed.

THE STEAM COACH OF 1803.

It is proposed to examine the evidence concerning the two engines separately, the first consideration is given to the steam coach of 1803, a picture of which (pl. xi, fig. 2), reproduced from the "Life" (vol. 1, p. 142), is before you.

We know with certainty that in 1801 Trevithick and his cousin Vivian built a road locomotive at Camborne, and that on Christmas Eve of that year it made its first public trial. The design probably resembled pretty closely the model in South Kensington Museum, but we must not overlook the statement made in the first edition of Alexander Gordon's "Elemental Locomotion" that a model he illustrates was the first locomotive model made by Trevithick. Gordon's engraving, from his third edition, is reproduced here (pl. xi, fig. 1). The resemblance to Catch-me-who-Can will be observed (pl. xii). There is no doubt about the Camborne engine, for we have contemporary account books and letters and a report in a Falmouth paper—quoted by Vivian in a letter written to Trevithick in London on February 23rd, 1802 (Ibid. p. 114). It was the success of that crude engine which led "Captain Dick" and Vivian to set about the preparation of an improved design, and which took them to London, where, on March 24th, 1802, they secured their famous patent. This patent covers the high-pressure engine as a whole, and the steam carriage is given only as one of several examples of the application of high-pressure steam. The patent drawing is reproduced in Francis Trevithick's "Life" (Vol. I., p. 128). A sectional elevation and sectional plan of the carriage is shown to a small scale on the top left-hand side of the sheet. That Trevithick and Vivian attached a great deal of importance to this part of their patent is evident from their letters on the subject, and especially from the fact that they decided to have a carriage built in London. The body work was entrusted to a Mr. Felton, of Leather Lane, E.C., and as the trial trips started from that quarter we may possibly assume that the engine was erected there. For the information of those who are not acquainted with the smaller streets of London, it may be mentioned that Leather Lane runs up from Holborn to Clerkenwell Road. The Holborn entrance is immediately on the left-hand side of Gamage's. It is a street of rather small shops and one or two factories.

Hoping that it might be possible to trace the history of Mr. Felton, and

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perhaps, through his descendants, find further particulars, an examination was made by the author of the splendid collection of London directories which are to be found in the Guildhall Library. In 1801 Felton occupied Nos. 35 and 36, Oxford Street, whither, as we shall see, he had moved from No. 254 a few months before. In 1803 he was in Leather Lane. There are no directories of 1804, so that we cannot say where he was then; but in 1805 his name disappears altogether. The first mention of him as a harness-maker and coachbuilder is in Kent's directory of 1797, when he was in Oxford Street. Thus his whole career in business in London would appear to extend over not more than six or seven years. Apparently he was not a member of a city livery, and it is pretty safe to assume that he was a person of little importance. Why or how Trevithick and Vivian came to employ him is unknown. It is of some interest to record that a William Felton wrote an important book on coach building and harness in 1794-5. Was he the same Felton?

What the nature of the work was that Felton did we have no accurate means of knowing. An entry in an account book of Andrew Vivian's ("Life" p. 140) reads "July, 1803.—To Felton, for building the *coach*, £83 5s." Henry Vivian, Andrew's son, wrote in 1845 (forty-two years after the trial), "Mr. Felton (who built the *carriage*, and he and his sons were with the engine all the first day it ran)." It will be observed that Andrew Vivian speaks of a "coach" and his son of a "carriage." What did they mean? If the patent drawing was followed, then we may assume that Felton and his sons constructed the body, wheels, underframe, &c. But it is equally possible that they built a special coach designed to be towed behind an engine. The description "coach" or "carriage" would apply almost equally well to either, but in favour of the accepted view that the patent drawing was followed, we may regard it as unlikely that Trevithick and Vivian would have gone to the expense of having a special coach built if the intention was only to tow it.

Trevithick himself wrote on May 2nd, 1803—"Life," p. 158—"The coach engine did not arrive in London until last Wednesday. The coach is ready to fix to the engine." He then gives particulars of an engine with a 5½ in. piston and 2½ ft. stroke, pressure 30 lb.

Francis Trevithick gives an account of the carriage which he obtained from Captain Joseph Vivian. Joseph was a lad in 1803, and the account was written presumably about 1870, when he must have been a very old man. It would be unsafe to accept it as literally accurate. Joseph was, of course, acquainted with the patent drawing, and it would certainly bias his memory. He says (Ibid. p. 142) "he thinks the engine had one cylinder and three wheels, the driving wheels behind were about 8ft. in diameter. The boiler and engine were fixed just between those wheels. The steering wheel was smaller, and placed in front. There were some gear wheels to connect the engine with the driving wheels.

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The carriage for the passengers would hold eight or ten persons, and was placed between the wheels, over the engine on springs." Francis gives the sketch herewith reproduced (pl. xi, fig. 2). He drew it, no doubt, from the particulars given by Joseph, with the help of the patent drawing. It must be regarded with the gravest suspicion. Can anyone suppose that Felton could have made the carriage part alone for eight or ten persons for £83 5s.? Note, too, that there is no means of access to the coach, the wheels being right in the way of the doors. The position of the driver is hopeless; his control of the steering wheels, with the handle sloped as shown, would be extremely poor; the patent drawing gives a much smaller rake. Again, it is rather improbable that wheels as great as 8ft. diameter were used. They would make about 200 revolutions per mile, and at five miles per hour they would revolve at about sixteen turns per minute. With such reduction gear as that shown the engine would make about twenty strokes, in and out, per minute. Now, the Tuckingmill locomotive of 1802, with a cylinder of 5½in. by 2½ft., made fifty strokes—probably revolutions—per minute. Trevithick knew he could run his engine at a higher speed than that, and would hardly go to the expense of having very costly wheels made for an experimental engine.

Let us now turn to the engine and boiler. When we come to examine the evidence closely we find not a particle of it that supports the statement made by Francis that the cylinder was horizontal.

It is believed, on the evidence of Mr. Hugh Hunter ("Life" p. 120), taken in 1869, that after the destruction by fire of the first, or Camborne, road locomotive it was replaced by a new locomotive which ran between Camborne and Tuckingmill in 1802 or the spring of 1803. We have no evidence as to the form or appearance of this engine; it may have been made from the remains of the first engine, or it may have been entirely new. In either case Francis assumes ("Life," p. 139) that it was the locomotive that was sent to London. But the evidence is not conclusive. Andrew Vivian's account book shows that in 1803, January, February and March, Harvey's were making a new cylinder and a new boiler, and in August, 1803, is the entry: "Paid Messrs. Foxes, shippers, Falmouth, for carriage of the engine to London, £20 14s. 11d. Henry Vivian wrote, in 1845: "They carried their engine to London about 1803" (Ibid. p. 121). These references may be to the Tuckingmill engine re-modelled, but they might equally well refer to a wholly new engine. If we accept Francis's statement, then we may say that a complete locomotive on wheels was sent to London, and it would not be very unsafe to surmise that it ran through London just in the form that it left Cornwall and that the coach that Felton built was trailed behind it.

The conclusion of the whole matter is that we know nothing whatever about this first London locomotive except that it did make several trips from

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Leather Lane, and that taken for all in all, it was not a great success. Its ultimate fate is unknown. Henry Vivian—page 140—appears to think it went to Merthyr Tydvil and worked on a tram road. This is a statement of some importance, as we shall see presently. Joseph Vivian says: "I heard afterwards that the framing of the engine got a twist, and she was used to drive a mill for rolling hoop iron; and also that she ran on a tram road laid down in Regent's Park." This, no doubt, would be the Euston Square enclosure, and the statement has, on that account, some significance.

Two items of evidence remain to be added. Stuart, in his "Anecdotes" of 1829, pp. 458-9, describes the carriage. Part of the description is put in inverted commas, but from what source it is drawn is not stated. The description is written as if made from an actual machine, but agrees so closely with the patent drawing as to arouse suspicion.

In the *Civil Engineer and Architects' Journal* of 1839 is one of the best early "lives" of Trevithick. It was written by Hyde Clarke, and parts of it reappeared in the short biography already referred to. In it occurs the following remarkable passage which will not be found in Francis Trevithick's "Life": "In 1804 . . . about this time . . . Trevithick put into operation the first locomotive engine in London. . . . The engine he used was about the size of an orchestra drum, and which he attached to a phaeton between the back wheels. With this carriage an experiment was made in Lord's Cricket Ground at Marylebone, several men of science alternately steering it, and expressing their perfect satisfaction as to the ease with which it was directed. From hence it was steered down the New Road and Gray's Inn Lane, to the coachbuilders, whence the phaeton was obtained. . . . The next day Trevithick took the same engine and exhibited it in a cutler's shop, working the machinery, which was one of his essays, to show its general applicability. Subsequently he had a temporary tramroad constructed within an enclosure on the ground now occupied by Euston Square. This road was of an elliptical form, and on it he ran his locomotive. It was opened to the public as an exhibition, and people crowded to see it; but the second day Trevithick, in one of his usual freaks, removed the engine, and, to the great disappointment of visitants, closed the ground. This he did under the impression that it was better to let the affair drop until he saw the opportunity to avail himself of it advantageously."

Further reference will have to be made to this passage after Catch-me-who-Can has been discussed. It looks very much as if Hyde Clarke had confused several engines. Smiles—page 67—where he refers to Trevithick in his life of the two Stephensons, 1874, does little more than paraphrase Hyde Clarke, and hence, assuming that Clarke was wrong, he perpetuates the errors.

Finally, we may note that Trevithick himself, in giving evidence before the Commission on Steam Carriages of 1831, said: "The first locomotive engine

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ever seen was one that I set to work in 1804 on a railroad at Merthyr Tydvil." It is extraordinary that in an inquiry on road vehicles he mentions neither the Camborne engine nor the London coach.

Some Technical Details.

A critical examination of the dimensions of the engine of the steam coach reveals many difficulties. It is unnecessary to say that the power which can be developed by any steam engine depends upon the amount of steam that the boiler supplying it can provide. A very good modern steam engine requires at least 10 lb. of steam per useful horse-power per hour. Many modern steam engines require 30 lb. to 50 lb., and even more. If we say that Trevithick required 30 lb. we shall certainly greatly under-state the quantity. But put it at that and let us ask what horse-power his boiler could generate. We have no definite particulars to go upon, but there is reason to suppose that the boiler was of his familiar type, with a wrought iron tube bent into the form of a U and placed horizontally inside the boiler shell. Now, it is impossible to see how he could have got more than 10 or 12 square feet of heating surface into the little boiler shown in the patent drawing—even when we reject the description of it as about the size of an "orchestra drum." He certainly could not count on more than about 5 lb. of steam per hour from each square foot of heating surface, or from 50 lb. to 60 lb. total per hour. That would give him at most 2 horse-power at the engine. We have taken the figures on the generous side, and actually it is fair to doubt that even that power could have been developed. But supposing it was, can we imagine such a vehicle as has been described—a coach capable of carrying eight to ten passengers—being propelled at all by it over such highways as existed in London at that time? We are forced to the conclusion either that the coach was a very small affair or that the boiler was very much bigger than that shown in the patent drawing, in Francis Trevithick's sketch, and in the "orchestra drum" description. Indeed, the impossibility of designing a boiler on the Trevithick model that could make enough steam to propel a coach and yet take up no more space than would be available, combined with the entire lack of contemporary evidence, and the remarkable fact that Trevithick himself, as far as we know, never alluded to the recorded runs, raises a doubt in the mind about the accuracy of the memories of those who many years after the event wrote descriptions of them. With our present knowledge of the steam engine and the experience that exists as to the propulsion of vehicles on common roads we can safely say that Trevithick's steam coach, as illustrated by his son, could not have worked.

Catch-me-who-Can.

Let us now turn to the London railway locomotive of 1808. It has already been mentioned that the contemporary evidence about this engine is very weak.

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The best of it was found by that indefatigable antiquarian, R. B. Prosser, and was published in an unsigned article contributed by him to *The Engineer* of December 18th, 1903, page 589. It would take too long to go through the article, but the substance of it was based on advertisements and paragraphs in the *Times*, the *Observer*, and the *Sun*, mentioning the racing steam engine and the proposal to pit it against a racehorse. The first reference appears in July 8th, 1808, and the last in the *Observer* on September 18th of the same year. The dates are important since they indicate the length of time that the railway at Euston Square existed. Thinking it probable that the *Globe*—now, alas! no more—which came into existence in 1803, and which always had a sporting column, would be likely to mention the engine, an exhaustive search of the files has been made, but has failed to reveal a single specific mention either in the editorial or advertisement columns, though a humorous passage about steam engines replacing horses appears in both the *Globe* and the *Sun* on July 21st, 1808.

An interesting item of evidence of a totally different kind exists. Some years ago, Mr. H.. C. Levis purchased in Charing Cross Road for a few shillings a drawing which has all the appearance of being a genuine Rowlandson. It shows the Trevithick enclosure with the engine and carriage. There can be little or no doubt that the well-known engraving which was cut by Welch for Trevithick's "Life" is based on the Rowlandson drawing. There are slight differences in the costumes, and in the scenery, but otherwise the resemblance is too close to be fortuitous. Now, Rowlandson's drawing is dated 1809; the artist died in 1827. When was the drawing executed? If it was made at the time of the trials it is hardly conceivable that the wrong date would have been put on it; if it was made only a year or two after the event it is not likely that the artist would have got wrong by a year. If, as experts who have examined it believe, it is indeed a genuine Rowlandson, then we must conclude either that the date was put on subsequently from a faulty memory, or that the drawing was made several years after the event, in which case its value as contemporary evidence will be much diminished. As a matter of fact, the matter is of small importance, for the drawing of the engine is too crude to permit its identification. Mr. Levis has very kindly permitted this invaluable drawing to be reproduced, and an engraving of it is before you (pl. xiii).

Fortunately there can be no doubt that the enclosure was built and that Trevithick did run an engine on rails within it. Let us accept that. The question we have to consider is, "What was that engine like?" Francis Trevithick assumed that it resembled the drawing of an engine which was used on Trevithick's business or trade card. He did so largely, if not entirely, on the statement of Mrs. Guilmard, Davies Gilbert's sister. That Mrs. Guilmard's statement is reliable it is legitimate, without discourtesy, to doubt. It is not

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at all probable that a lady would take a critical view of a sketch, and it is more than probable that anything that looked like the engine she knew would pass muster. To most people, and to nearly all women, a locomotive is a locomotive and nothing more. A copy of one of these trade cards (pl. xii) is here reproduced from Miss Edith K. Harper's delightful little biography of Trevithick, called "The Cornish Giant," with her permission and the permission of Messrs. E. and F. N. Spon, the publishers.

The date when Mrs. Guilmard wrote her memorandum is not known, for it certainly was not written in the year 1808, as Francis Trevithick's footnote—page 192—would lead one to suppose. The year 1808 given in that note is probably a misprint. The memorandum says the trial "took place on a waste piece, now Torrington Square." As that square was not begun till the late thirties, it is evident the memorandum was written at least twenty years after the event. Torrington Square, it should be added, is just behind the British Museum, and, as a consequence, about half a mile from Euston station. Isaac Hawkins ("Life," p. 195), in a letter to the *Mechanics' Magazine* of March 27th, 1847, makes the site the southern part of Euston Square, and Albinus Martin, 1868, gives it as very near, if not exactly where the North-Western Railway station stands. All three, it will be seen, indicate the same neighbourhood, but they leave the exact position in doubt. Fortunately, the contemporary advertisements found by Mr. Prosser, and already referred to, put the actual site beyond question. It was an area known as Bedford Nurseries, which are shown on maps of the day as occupying the position now filled by Euston Square.

Whilst it may be accepted without reserve that Trevithick did build a railway in London and did certainly, at the end of July and possibly later, run a locomotive on it, it cannot with any certainty be stated that that engine was like the familiar sketch of Catch-me-who-Can. In a letter of Trevithick's, dated 1808, he tells Giddy that he intends "to put the inscription on the engine which you sent to me," but he does not mention what the inscription was, and we cannot be sure that he meant a name at all.

Technical Details.

The celebrity attained by this engine is due in the first place to the extreme simplicity of the design, and in the second to the fact that it was propelled by a single pair of smooth wheels on smooth rails. If it actually took the form shown in the drawing, it antedates, as far as the engine part is concerned, the Sanspareil of Hackworth, and is the progenitor of the Rocket. It will, therefore, be of interest to examine the scanty technical particulars that are available.

We have first Isaac Hawkins' description, written in 1847 ("Life," p. 193). Hawkins was an engineer of some eminence, and is a fairly reliable witness. He

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states that the engine weighed about 10 tons, and travelled at twelve miles an hour by his own timing. Then we have particulars given by Albinus Martin in 1808 (Ibid. p. 195). "The engine itself," he wrote, "was to me a entire novelty, but not differing in general appearance from that on the Merthyr tram road, and of which an engraving has been published." Thirdly, we have the description given in Bendy's letter of November 8th, 1840 (Ibid. p. 240), and distorted by Francis Trevithick (Ibid. p. 197) into a manifest absurdity. Bendy writes of two engines; one made in 1803 for a dredger, and the other, an engine not specified but belonging to the "Trinity Company and Government." The first engine had a cylinder 14½in. diameter with a stroke of 4ft. Francis mixed up the two engines and wrote —as if quoting from Bendy—"The engine used in the dredger was of the same size as that fixed in London to run round the circle at the speed of fourteen or fifteen miles an hour—the cylinder was 14½ inches diameter, with a stroke of 4 feet."

If Francis had examined this statement he could not have failed to see the folly of it. A locomotive designed on those proportions would have been bigger than a mastodon. The wheels would have been 8ft. diameter, the boiler about 10ft. diameter, the height to the top of the chimney some 20ft., and the length overall 17ft. or 18ft. We need not trouble to discuss the weight, but it would have been certainly in the neighbourhood of 30 tons. If Bendy was right in saying that the London engine was the same size as the Trinity House engine, then that engine must have been much smaller than the dredger engine of 1803.

We have Trevithick's own statement—page 192—that the engine weighed about 8 tons—that is on the assumption that his letter of July 28th, 1808, refers to Catch-me-who-Can. If of those 8 tons we may give 5 to the boiler and contained water, then the diameter of the boiler would have been about 5ft. and its length between 9ft. and 10ft. If it was 5ft., then the stroke must have been about 2ft. and the diameter perhaps 7in. or 8in. A boiler of these probable proportions would develop steam equivalent to between 8 and 10 horse-power.

It will be seen that even on the proportions here suggested the engine would have been a very big one, and a doubt rises to the mind if there is not a mistake in Trevithick's estimate of the weight—8 tons. The Newcastle engine weighed, in working order, only 4½ tons; it had a horizontal cylinder 7in. diameter with a 3ft. stroke. Its boiler was 4ft. diameter by 6ft. 6in. long. It had a fly-wheel and gear wheels, and was altogether of a heavier type than Catch-me-who-Can. We have fortunately a working drawing of this locomotive, from a careful measurement of which it is possible to estimate that it could develop between 5 and 7 horse-power—quite sufficient for the object Trevithick had in view.

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The statement by Albinus Martin that the London locomotive did not differ from the Merthyr engine "of which an engraving has been published," will not have escaped attention. Martin, we gather, had not seen the Merthyr engine himself, but he was acquainted with the drawings given in various periodicals—in the *Mechanics' Magazine* for December 22nd, 1838, or in Alexander Gordon's "Elemental Locomotion," of 1832 and 1834, or in the "Penny Cyclopedia," quoted in the "Life," page 207. Francis Trevithick implies that there is no record of a Merthyr engine. Gordon says plainly that the engine he illustrates was a model. Indeed, in his first edition—1832—it has no funnel and, like the South Kensington model, was fired with a lump of red-hot iron. The resemblance to Catch-me-who-Can is striking. On the whole, this statement of Martin's is the best evidence we have as to the appearance of the London locomotive of 1808. Unfortunately it was written in 1868, sixty years after he had seen the engine; but we must not forget Henry Vivian's statement, already quoted, that he thought it went to Merthyr Tydvil and worked on a tram road.

Can it be denied, when the various points that have been brought forward are weighed and considered, that Trevithick's London locomotives are still shrouded in mystery? Yet there is a possible solution. Was the first Camborne engine really destroyed by the fire in the shed, or did it become the second Tuckingmill engine? Was Hyde Clarke right? Were the first Camborne engine, the London road locomotive, and the racing steam horse which ran round the enclosure all one and the same engine slightly modified? Was Felton's coach drawn behind it from Leather Lane to Lord's and back, and was it the same coach that travelled round the circular railway? There are a good many things that point to that suggestion as the solution of the mystery, but more evidence is required before it can be advanced with certainty.

Conclusion.

In bringing this inquiry to an end a tribute must be paid to the extraordinary genius of Trevithick lest it should be supposed that because a mystery surrounds two of his inventions any damage is done to his reputation. His genius is supported by too many well-attested inventions to suffer even in the smallest measure from the doubt that exists about the nature of two of them. To Captain Dick, the Cornish giant, the world owes more than to any other single engineer, not excepting Watt himself. To him we are indebted for the double-acting high-pressure engine, and it matters relatively little what else he did or did not do. That fact alone is enough to place him, and to preserve his memory for ever, on the highest pinnacle attainable by engineers.

The paper was illustrated by the Rowlandson drawing, kindly lent by Mr. H. C. Levis (pl. xiii); by an early Trevithick locomotive model and some

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drawings, lent by the Director of the Science Museum; by another original model lent by Mr. E. D. Lowy (Member); and by an original Trevithick visiting card, whereon was a representation of the 1808 engine, lent by Miss Harper (pl. xii).

DISCUSSION.

Mr. Jenkins mentioned that he had searched without success for documentary evidence about Trevithick's locomotives. He commended the author's suggestion to members to keep on the look-out. Both Dr. Philip Norman and Mr. Dendy Marshall declared their belief in the genuineness of the Rowlandson print, which was the important piece of evidence brought forward that evening. They based their opinion on the characteristic drawing and colouring of the figures; indeed, Dr. Norman considered the drawing a good example of the artist's work. In his opinion the subscription on the drawing mentioning Euston Square, which was not built till 1825, was not in Rowlandson's handwriting.

Upon this point Mr. Legros instanced his own father, who, although celebrated as an artist, was quite unreliable about his subjects. The speaker had obtained more information at the British Museum than from his father. It was quite probable that Rowlandson had made a mistake in the date.

Major Hurlstone Hardy mentioned the work done by Bennet Woodcroft, F.R.S., of the Patent Office, in the preservation of early engineering relics. In the "sixties" he had made a vigorous search for Trevithick's locomotives with very little result.

Mr. Harvey Trevithick, great-grandson of the inventor, described his own attempts to get details from his family. He believed there were still some of Richard's letters at Hayle.

Mr. Lowy said he had bought his Trevithick model in Lincoln some twenty-five years ago, but unfortunately he had been unable to trace its history further back than to the father of the then owner. He thought his model was of later date than that at South Kensington, because it was heated by a spirit lamp instead of a lump of hot iron.

Mr. E. A. Forward said he had investigated with some care the evidence on the subject of the early Trevithick engines. After giving a review of it, he expressed the opinion that both the models shown were genuine and of about the same date, viz., 1802. He was surprised that the author should have cast doubts on Trevithick's own dimensions of the 1803 engine, as they were the only reliable figures they had. By 1803 Trevithick engines were being regularly made of 3, 4, 5, 6 and 8 h.p., and probably the locomotive was only one of these engines on wheels. The drawing of the Pen-y-darren engine was manifestly wrong, as the fireman would have to lie on his stomach to get at the fire. He disagreed with the author's low estimate of the horse-power of the 1803 engine.

In replying to the discussion, Mr. Pendred said that he was satisfied that the authenticity of the Rowlandson drawing could be now said to be established.

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He did not think the employment of a spirit lamp indicated that Mr. Lowy's model was the later of the two, as Murdock had used a spirit lamp in his 1786 model. Mr. Forward's strictures of the Pen-y-darren drawing, because of the fireman's difficulty, did not necessarily hold good, as the latter could stop the engine and get down to stoke the fire. As a final explanation, the author threw out the suggestion that the three locomotive engines were really only successive adaptations of one engine.

A vote of thanks to Capt. H. Riall Sankey and the Marconi Company for the use of the hall, and to those who had kindly lent models and drawings, brought the meeting to a close.

MR. E. A. FORWARD, A.R.C.S. (*Communication*).—The suggestion that such old diaries and memoranda of engineers of the period, as were accessible to members, should be searched for any mention of Trevithick's locomotives, led me to look through the journals and papers[1] of Simon Goodrich, M.Inst. C.E., with results that are worth recording.

First of all a few words as to the diarist himself. Simon Goodrich was born on October 28th, 1773, and on December 25th, 1796, entered the office of Sir Samuel Bentham, K.B., Inspector General of Naval Works. Goodrich continued to be employed by the Navy Board from that time onwards, and held the position of "engineer and mechanist" at the time of his retirement in 1831. During Bentham's regime, Goodrich was his right-hand man and carried into effect the various engineering schemes proposed by the former for H.M. Dockyards. His official position thus brought him into contact with most of the eminent engineers of the day, not the least among these being Richard Trevithick.

Goodrich's journal and memorandum book is not uniformly complete over the whole period. The existing volumes commence in 1802, and continue with gaps until 1845; they contain interesting references, relating to engineering works of all kinds which came under his notice; we are concerned here only with references to Trevithick's locomotives.

The earliest and most valuable item found is a memorandum on a foolscap sheet watermarked 1801. The exact date when it was written is not given, but "about 1800" has been written on it by Goodrich subsequently. The contents, however, as will be shown, fix the date as March or April, 1803, when Trevithick was in London and probably communicated the information personally to Goodrich. The memorandum reads as follows:—

"Mr. Trevithic's engine at Colebrookdale consumed 112 lb. Coals pr. hour, 30 strokes per min., Dia. of steam cylinder 5 in., length of stroke 3 ft., worked a Double Pump 3 ft. stroke 10 in. Diam. raising the water 37 high,—about 230,000 lb. 1 ft. high in a minute. 1 cwt. of coals. This experiment was made under unfavourable circumstances—14 million with 1 cwt. 1 ft. high. Mr.

[1]Preserved in the Science Museum, South Kensington.

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Trevithic found the best of Mr. Bolton's engines with strong Welch coals lift 20 millions 1 ft. high with 1 cwt. of coal—this was when the Engines were in good trim and with the large engines of 150 horse power, Pumps 9ft. stroke."

"Mr. T. has prepared an Engine for driving a coach, diam of Cylinder 5½ stroke 2 ft. 6 in. 50 strokes per min't. work on each side piston 20 lbs. pr. inch, in the boiler 30 lb.—about 110,000 lb. 1 ft. high in a minute. The whole engine, fire and all is 6 cwt. The whole is contained within a cylinder boiler—2.9 long, 2.6 diam."

Following the memorandum is a carefully drawn pencil sketch, to a scale of 1 in. to a foot (pl. xiv). It would appear that at some subsequent time, in looking over the memorandum, Goodrich wrote "about 1800" at the top of the sheet, and amended the pressure on the piston of the coach engine from 30lb. to 20lb.

From the similarity of the figures given in the first paragraph to those given by Trevithick to Mr. Giddy in the letter dated August 22nd, 1802,[2] it would seem that Goodrich's memorandum refers to the same engine, which at that time had just been tested. He, however, gives the cylinder diameter as 5in., instead of Trevithick's 7in., and at the same time gives the lift as 37ft., as against Trevithick's 35ft., so that it would appear as though Goodrich had transposed the 5 and the 7 in the hurry of writing the note. It is to be observed that the duty given is calculated on the assumption that the 30 *strokes* per minute mean *revolutions* of the crank.

Goodrich was absent from London during the first two months of 1803, but Trevithick was in town early in April of that year and was sent for to the Admiralty Office to explain his engine. An officer was then sent to inspect an engine just erected in London.[2] There can be little doubt that Goodrich was the officer concerned, also that the occasion was the first upon which he met Trevithick. It is highly probable, too, that the memorandum was written at that time.

Trevithick's letter of May 2nd, 1803[3] contains the only authentic information about the London coach engine. He gave the cylinder diameter as 5½in., and the stroke 2ft. 6in., and said that it had worked with perfect satisfaction at 50 strokes per minute with a steam pressure of 30lb. The chimney was 2ft. high, and the engine had arrived in London on the Wednesday before he wrote.

Goodrich's memorandum gives us the additional information that the complete engine and boiler weighed 6 cwt., and that the whole was contained in a cylindrical boiler, 2ft. 9in. long and 2ft. 6in. diam.; the latter dimensions

[2]Trevithick's Life, Vol. I., page 153.
[3]Ibid, Vol. I., page 158.
N.B.—Blocks for the Plates XI. to XIV. have been kindly lent by the Editor of "The Engineer."

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show that Hyde Clarke's "orchestra drum" description was not far from the truth. The figure given for the power of the engine can only be obtained on the assumption that the 50 strokes per minute really meant revolutions, and that the steam pressure was actually throttled down to 20lb. in the cylinder.

Turning now to the sketch, which shows longitudinal and transverse sections of the engine and boiler, we see that while it resembles generally the patent drawing, internally it is quite different. The shell appears to be made of wrought iron, about 0.25in. thick, with flat ends flanged round outside the barrel. The furnace tube is 21in. diam., runs the whole length of the shell, and has a flat end with a small water space behind it. The grate occupies the full length of the tube, inclining slightly downward towards the back, and has an area of 4 sq. ft. Near the rear end of the furnace two oval flue tubes, measuring about 7in. by 5in., branch out and return, one on each side, passing through the front plate, and being connected by a breeches tube with the chimney, which is about 6in. diam., and finishes approximately at the height of 2ft. above the boiler. The water space is comparatively small.

On calculating the heating surface of this boiler, it is found to be about 21 sq. ft., exclusive of the portion below the grate, which is 5 sq. ft. Mr. Pendred thought that with Trevithick's ordinary return flue design, it would be impossible to obtain more than 10 or 12 square feet of heating surface, but with this design almost twice as much surface is obtained. Consequently the horse-power of the boiler, using Mr. Pendred's figures, would be nearly 4 instead of only 2; actually the engine itself developed about 3 horse-power according to Goodrich's figures.

The sketch shows the cylinder lying horizontally close to the top of the boiler, and the projecting end, which carries the steam cock, rests on the coach axle; the large circle, struck from the centre of the latter, is obviously intended to represent the coach wheel, and is 8ft. diameter. The four-way cock is shown, together with the exhaust pipe leading into the chimney. A cross-section of the cylinder is also added to show the steam port leading to the inner end. In the sketch, the cylinder is shown rather too near the shell to admit this steam port along the top. It is to be regretted that the sketch shows no more of the coach or gearing, and still more so that Goodrich did not leave a record of his having seen it running. It is not known whether he saw the engine at the time the memorandum was made, but probably he had not, as it appears from Trevithick's letter of May 2nd, 1803, that it did not arrive in London until April 27th of that year.

In the Journal itself, the first note of Trevithick's engines occurs on March 9th, 1804. Goodrich then records that "Mr. Homfray, Iron Founder from Pendarron Works in Wales," had been in town and invited him to go down to witness experiments with Trevithick's engines, but that the journey was

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to be deferred for a month. This was the Pen-y-darren locomotive, and two letters from Homfray have been preserved which deal with these proposed trials and the reason for their postponement. These agree with similar letters in the "Life" (Ibid, pp. 159-161), and from them it appears that Goodrich and Lieut. Cunningham, of Woolwich, were the two engineers deputed to make official tests of the engine at Pen-y-darren. The accident to Samuel Homfray, which caused the trials to be postponed, is detailed in the second letter dated March 7th, 1804, and this appears to have put off the trials for good, as there is no record of Goodrich having visited Pen-y-darren at that time. We are thus deprived of an authentic contemporary account of the Pen-y-darren locomotive of 1804.

The next mention of Trevithick in the Journal occurs on January 3rd, 1807, when he called on Goodrich and promised to call again with the small model of his steam engine. On Monday, January 5th, he brought the model and exhibited it under steam on a large table. A very complete description of the model is given which exactly agrees with the three-wheeled model now in the Science Museum, and unless there were other models absolutely identical, it shows that this model was in Trevithick's possession at that date.

Coming now to the year 1808, in which the London track locomotive was run, the Journal tells us nothing, and in fact is quite blank from June 23rd until August 12th, which period covers much of the time during which the engine was running. Trevithick, moreover, called on Goodrich on September 3rd to consult him about plans for completing the Thames Archway, but nothing appears to have been said about the locomotive which was probably swamped by Trevithick's difficulties in connection with the Archway.

We have, thus, to thank Simon Goodrich for at least one extremely valuable link in the history of Trevithick's locomotives, although at the same time it is most tantalising to find that he was prevented by circumstances, or by the loss of parts of his Journal, from leaving us more on the same subject.

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The Invention of Roller Drawing in Cotton Spinning.

By Alfred Seymour-Jones, C.B.E.

(*Read at the Birmingham Free Reference Library on June 16th*, 1921.)

In this paper I shall trace briefly the rise of the Roller Drawing system which has made possible the vast cotton spinning industry throughout the world, and which is intimately associated with the name of Sir Richard Arkwright. Few inventions have aroused greater controversy, prejudice and animosity in according credit where it is honourably due. The outstanding claimants are Lewis Paul (1738) and Richard Arkwright (1769). The Paul claim is countered by that on behalf of his associate, John Wyatt.

Our earliest record of roller drawing is to be found in the patent granted to Lewis Paul in 1738 (No. 562). The specification of this patent is witnessed by John Wyatt and another; it contains the following description of the invention or inventions:—

"The said machine, engine, or invention will spin wooll or cotton into thread, yard or worsted, which, before it is placed therein, must first be prepared in manner following (to wit):—All those sorts of wooll or cotton which it is necessary to card must have each cardfull, batt, or roll joyned together, so as to make the mass become a kind of rope or thread of raw wooll. In that sort of wooll which it is necessary to combe, commonly called jarsey, a strict regard must be had to make the slivers of an equal thickness from end to end. The wooll or cotton being thus prepared, one end of the mass, rope, thread, or sliver, is put betwixt a pair of rowlers, cillinders, or cones, or some such movements, which, being turned round by their motion, draws in the raw mass of wooll or cotton to be spun, in proportion to the velocity given to such rowlers, cillinders or cones. As the prepared mass passes regularly through or betwixt these rowlers, cillinders or cones, a succession of other rowlers, cillinders, or cones, moving proportionately faster than the first, draw the rope, thread, or sliver, into any degree of fineness which may be required. Sometimes these successive rowlers, cillenders, or cones (but not the first), have another rotation besides that which diminishes the thread, yarn, or worsted, (vizt.): that they give it a small degree of twist betwixt each pair, by means of the thread itself passing through the axis and center of that rotation. In some other cases only the first pair of rowlers, cillenders, or cones are used, and then the bobbyn, spole, or quill upon which the thread, yarn or worsted

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is spun, is so contrived as to draw faster than the first rowlers, cillenders, or cones give, and in such proportion as the first mass, rope, or sliver is proposed to be diminished."

We have here a specification disclosing two constructions: the first describes the underlying principle of roller drawing, wherein two or more pairs of rollers are employed; the second construction calls for only two rollers to act as feeders to the spindle which, by twisting and winding faster than the rollers yield, produces a similar effect to that of roller drawing. Unfortunately no drawings were filed, thus much remains obscure.

Paul, assisted by Wyatt, either licensed or sold machines made under his patent to several parties. The names of Mr. Johnson, Spitalfields; Mr. Cave, Nottingham; Mr. Thomas Warren, Birmingham, are given, with others, by Robert Cole in his paper on Lewis Paul as operating engines in their respective towns. From Dyer's poem, "The Fleece," (see below) we learn that engines were operated in a mill situated in the Vale of Calder, Yorkshire. Daniel Bourne, Leominster, Herefordshire, would also appear from Cole to have employed Paul's engines in his mill.[1] In spite of these sources of income, Paul and Wyatt suffered imprisonment for debt, and parted company about 1743. Wyatt later on entered the service of Matthew Boulton, of Birmingham.

It was early impressed on the adventurers that the kind of stock cards then in use was unable to produce a feed of uniform and continuous sliver. In 1748 Paul was granted a patent (No. 636, August 30th) for a carding engine.[2] This patent was anticipated in some respects by that of Daniel Bourne, who obtained a patent on January 20th, 1748 (No. 628).

Paul was granted a third patent in 1758 (No. 724); to this specification excellent drawings are attached. These disclose a strong similarity to the second construction contained in his 1738 patent [p. 50], suggesting that the drawing roller principle was never employed, or, if employed, was a failure. Two pieces of evidence will enable one to form a conclusion on the point whether Paul ever operated the roller drawing system.[3] The first is contained in a poem, written by

[1]Robert Cole mentions in his paper on Lewis Paul, appended to French's Life of Samuel Crompton, that he had in his possession various letters from Paul's customers, and mentions Bourn [sic] as among them.

In the "Gentleman's Magazine," Vol. XXIV., p. 482, 1754, Thursday, October 24th, is an interesting extract:—"Leominster. The Curious Cotton works, with the whole building wherein they stood, was consumed by fire, to the immense loss of Mr. Bourne, the artist who erected them, and the poor therein employed. Besides the loss of the partners who had shares in them, the single loss of Mr. Bourne is computed at £1,600."

[2]Wyatt MSS. Letter from Paul to Wyatt. Jan. 7th, 1739. "By this time I hope you have completed the carding machine according to the instructions I left. . . ."

There are further documents relating to this subject which show that Wyatt had some share in the invention.

[3]There is a document dated June 9th, 1735, from "Mill," which deals specifically with the roller drawing principle. Who or what was "Mill" I have not been able to fathom.

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John Dyer, entitled "The Fleece," published in 1757, or one year before Paul obtained the final patent referred to. Dyer says in Book III., lines 79—85:—

"But patient art,
That on experience works, from hour to hour,
Sagacious, has a spiral engine form'd,
Which, on an hundred spoles, an hundred threads,
With one huge wheel, by lapse of water, twines,
Few hands requiring; easy-tended work,
That copiously supplies the greedy loom."

[Dyer's footnote: "Paul's engine for cotton and fine wool."]

Further on in the same book, lines 291-302:—

"We next are shewn,
A circular machine, of new design,
In conic shape: it draws and spins a thread
Without the tedious toil of needless hands.
A wheel, invisible, beneath the floor,
To ev'ry member of th' harmonious frame
Gives necessary motion. One, intent,
O'erlooks the work: the carded wool, he says,
Is smoothly lapp'd around those cylinders,
Which, gently turning, yield it to yon cirque
Of upright spindles, which, with rapid whirl,
Spin out, in long extent, an even twine."

[Dyer's footnote: "A circular machine,—a most curious machine, invented by Mr. Paul. It is at present contrived to spin cotton; but it may be made to spin fine carded wool."]

Dyer gives us an excellent description of Paul's second construction contained in his 1738 patent, and of his invention patented in 1758 (pls. xv and xvi). He fixes the engines by his footnotes as being Paul's patents. Throughout the poem we do not read of the roller drawing system.

The second piece of evidence is an expert's opinion. John Wyatt, when he died, left his family a note which reads: "The inclosed yarn, spun by the Spinning Engine (without hands) about the year 1741."

That yarn would have been spun on the machines operated in 1741 under the 1738 patent. It was submitted about fifty years afterwards to Mr. John Kennedy, of Manchester, a recognised authority on the subject, who said: "From examining the yarn, I think it would not be said by competent judges, that it was spun by a similar machine to that of Mr. Arkwright's, for, the fabric or thread is very different from the early productions of Mr. Arkwright, and is, I

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think, evidently spun by a different machine, the ingenuity of which we cannot appreciate as the model alluded to is unfortunately lost."[4]

That is the most conclusive evidence I have been able to discover throwing any reliable light on the special system used by Paul in his spinning engines, and it does not justify the claim made on his behalf of anticipating Arkwright's system.

Paul died in 1759, and was buried in St. Mary's Parish Church, Paddington.

The right of Lewis Paul to the inventions set out in his 1738 patent has been questioned by Edward Baines in his "History of the Cotton Manufacture" (1835). Robert Cole, F.S.A., read a paper (already referred to) before the British Association at Leeds in 1858, in which he quotes, *in extenso*, from Paul's papers which had come into his possession (since then they have unfortunately been burnt). He endeavours to justify Paul as the true inventor of the cotton spinning system, but, like many others, he avoids specifically mentioning the real issue, that of roller drawing, the only system employed for cotton drawing. His paper clearly shows the relationship which existed between Paul and Wyatt, mainly financial, but he fails to be of real assistance to us in our quest.

The Birmingham Reference Library is fortunate in the possession of a collection called the "Wyatt MSS." These are a series of documents and letters between Wyatt and Paul, Wyatt and his brother, and others, but from our standpoint they are uninteresting. Those between 1730 and 1738 are too often acrimonious, mainly quarrelling over finance. The documents are mostly in John Wyatt's handwriting and, unfortunately, few are dated.[5] They appear to have been written at varying periods, and at some time Wyatt appears to have endeavoured to fix approximate dates to them, but the nearest he could get was: "that it must have been after they went to London." His early documents are crude, but his later ones excite little but admiration. There are many referring to roller drawing and the system of spindle drawing. I give one on roller drawing as an example. It is undated, but placed among the 1738 series. Omitting the first part which deals with the preparation of the cotton:—

The principle parts necessary to every Bobbin comes to the regular diminishing of the above preparation which is done by means of cylinders, rollers, or cones, the convex part of whose surfaces are in some cases made smooth in others rough, indented, or covered with leather, cloth, shagg, or sometimes with hair or bristle brushes, or with points of metal set in wood, or being fixed in leather first, and afterwards wrapped about the cylinders. Which makes it in some measure resemble the face of the common cards

[4]John Kennedy's paper, "The Rise and Progress of the Cotton Trade."—Mem. Manchester Lit. and Phil. Soc., 1819, vol. III., p. 137.

[5]The arrangement of the Wyatt MSS. has been well done, but it seems to me that as Wyatt's handwriting and spelling improved year by year, an expert in handwriting would place some of the undated documents differently.

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at present in use. In some cases the wool is drawn by means of several pairs of these cylinders, etc., one pair moving in its circular surface as much faster than the other as the wool given is made less without twist at all, as for example if the sliver or rolls joined as above, were required to be drawn to a size no greater than one sixth part of what they were before, then must the velocity of the circular surface of each pair of cylinders be in proportion to each other as 1 to 6. In some cases a small matter of twist is given betwixt those pairs of cylinders which is done by making the pair move quickest (which are fixed in ring or hollow cylinder) move at the same time through whose centers of motion the thread itself moves. When cylinders are fixed in a ring the ring itself may be kept in the circular direction by means of pulleys so fixed that the outward rims may be directed by them. When the cylinders are fixed in a hollow cylinder then the outside of the cylinder itself being put through holes or the like keeps the cylinder in motion. In other cases only one pair of cylinders, etc., is made use on and then the bobbin, spool or quill upon which the thread or yarn is wrapt as it is spun is made to exceed a certain arm or guide that places the thread regularly on the spool, quill or bobbin in greater degree as the thread is to be made less than the quantity of wool given to the cylinders. N.B.—Whether the revolutions of the bobbin exceed the revolutions of the arms or whether the revolutions of the arms exceed the revolutions of the bobbins the effect is nearly the same."

That document is so like the patent specification in its wording as to suggest that it was drawn up as the instructions for its preparation. That Wyatt intended others to know his position in regard to the patent would appear from an undated document: "A Descripion of Mr. Paul's Invention for Spinning," at the end of which he uses the words, "We Petitioned His Majesty's Royal Patent," etc.

Unfortunately, throughout the Wyatt MSS. there is no evidence whether Paul or Wyatt, or both, were the inventors of the roller drawing principle. Wyatt writes as much of the spindle drawing method as of the roller drawing system. All evidence goes to show that Paul and Wyatt never carried the roller drawing idea beyond the experimental stage. That they launched the spindle drawing engine is to be found in an important admission by Wyatt, though one document is endorsed, in pencil, 1760, it may have been written about 1738. It is headed and written by Wyatt.

"Thoughts Originally Mr. Paul's."

1. The joyning of the Roles.
2. Their passing through cillinders.
3. The calculation of the wheels by which means the Bobbyn draws faster than these cylinders I presume was picked up somewhere before I knew him.

"Thoughts Originally Mine."

1. The Horizontalls and Tracer.
2. Conick Whorves.

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3. The making the Spindle twice the Length of the Bobbyn, with the Ring flys and manner of raising the Bobbyn.
4. With the Wheel Pipe which serves all the Bobbyns or any Bobbyn.
5. An Original design of this long Spindle and Short Bobbyn was to work with only one wheel, whorve, or Pulley, which turned the Spindle only. The Role being Drawn, to the size of the Thred without twist. This method if the Roles can be made quit regular seems to be about the highest perfection the thing is capable of, in this case the Bobbyn is brought about by the strength of the thred only. Therefore to proportion the friction of this Bobyn to the strength of the thred is some difficulty. (This not being rightly hit upon at first; Master Paul was impatient with it. It was then altered to the wheel and Pipe.) The bobyns
6. in this case must have a contrivance to prevent its going faster than the Spindle in case of irregularity in the engine or any suden stops. I think the best means I have yet thought on for this is a spring fixed upon one end, and near the outside of the Bobbin the other end Bearing very gently against the Spindle at such an Angle as if the Bobbin should offer to out go the spindle the end spring may bind so hard against the spindle as to stop it soon.
7. Or the cones and conick wheels in various cases.
8. In the new work made at Mr. Bartletts the maner of driving the spindles by wheel and strap Impraceing the whorves on both sides.
9. The manner of laying the Thred upon the Bobbin by Thred instead of an Iron Screw which was Mr. P——s original method.
10. A means to take off the friction of the axis of the two great wheels and prevent the Gudgeons get in so soon (?loose) by the interposition of two friction wheels to bear against each other and against the shafts of the great wheels.

"I may say the whole contrivance of that work whether it prove better or worse is all my own. Two things I already apprehend might have been Better viz If the wheels had had their Rims Bent in thickness and been so contrived as to have Born against each other instead of y[e] two friction wheels above."

In view of the foregoing admissions we may reasonably assume that both Paul and Wyatt contributed to the invention of the roller drawing principle. It was merely an enunciation of a principle in the patent and not a description of any combination.[6]

After Wyatt entered the service of Matthew Boulton he made many inventions. The celebrated weighbridge, in use throughout the world, is his. His researches into friction annihilators produced the roller bearing, now so common.

[6]Wyatt endeavoured to improve the spindle and bobbin in order to make automatic winding. Arkwright's spindle and flier is most crude, necessitating stopping the frame working to allow of readjustment of the thread. Neither appears to have known of the Saxony spindle, or of Leonardo da Vinci's (circa 1500 A.D.) beautiful automatic self-raising spindle and flier so clearly drawn in his "Codex Atlanticus."

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Road construction, bridge building, hydrostatics, canals, water power engines, and many other schemes received his attention.

John Wyatt died in 1766, and was buried in St. Philip's Churchyard, Birmingham.[7] Many of the leading men of Birmingham, including Mr. Boulton, attended the funeral.

Arkwright's Inventions.

In 1769, Richard Arkwright patented the roller drawing principle and working combination which exists to-day.

Arkwright was a barber by trade.[8] He was the youngest child of Thomas and Ellen Arkwright (née Hodgekinson), a beautiful woman. They had seven children, two boys and five girls, and not thirteen as is commonly stated. The eldest son joined Prince Charles Edward when he made his descent on England *via* Preston in 1745. I have been unable to trace his further career. The five daughters married men connected more or less with the cotton industry. Mrs. Arkwright was left a widow a few years after Richard's birth in 1732 and in poor circumstances. Having little or no financial support she went to live with one of her married daughters in Manchester, and Richard was apprenticed to a barber at Kirkham, near Preston. After serving his indentures, Arkwright went to Bolton-le-Moors, Lancs., where he practised his trade. About 1766 he became interested in the cotton spinning problem, which had become acute through John Kay's invention of the "fly shuttle" in 1733, and that of his son Robert's invention of the "drop box" in 1760, causing a famine in the supply of warp and weft. While pursuing his invention he maintained the closest secrecy by building his machine in Manchester, probably under the protection of his relatives. In the spring of 1768 he exhibited his perfected machine in the back room of the Old Grammar School at Preston, whither he went to obtain financial support from among his parents' friends. The only help came from John Smalley, a wine merchant and painter, who sold out his business, it is said for about £1,600, and joined Arkwright, but on what terms I have not been able to discover. The repayment of this debt would appear to have happened by John Smalley building the cotton mill at Holywell, Flintshire, in 1777.[9] With this limited capital the adven-

[7]Opposite the Blue Coat School door, and close to the railings in St. Philip's Churchyard (now the Cathedral), Birmingham, is an upright gravestone. It reads: "In Memory of John Wyatt, who departed his life November the 29th, 1766. Aged 66 years. Likewise of Marabella, his wife, who died February the 4th, 1776. Aged 54 years." Marabella was Wyatt's second wife.

[8]The information relating to the Arkwright family has been obtained from the Willersley MSS. kindly loaned to me by Mr. F. C. Arkwright.

[9]An interesting account is given of John Smalley and his Holywell Cotton Mill by Thomas Pennant in his "History of the Parishes of Whiteford and Holywell," 1796, page 214 *et seq.*

John Smalley was buried in Whiteford Churchyard; at the N.W. end of the Church is a big altar tombstone: "Here rests the remains of John Smalley, late of Preston, in Lancashire, he died at Holywell on the 28th day of January, 1789, aged 53 years, he established the cotton manufactury in the year 1777."

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turers departed to Nottingham and started a mill in Woolpack Lane. Their operations would probably have been commenced about June, 1768, as they left Preston after the Burgoyne election, which took place in March or April of that year. At this election, Arkwright was so shabbily dressed that his friends purchased a new suit in order that he might appear, to vote as one of Preston's Freemen, respectably clothed.

What with the equipping of the Woolpack Lane Mill and the high price of cotton, the small capital did not suffice without assistance from their bankers, Messrs. Wright. These funds were exhausted during the last days of 1768 or the early days of 1769, and Arkwright was in deep waters, financially.

It is apposite I should detail, at this stage, the true story of the quarrel between Arkwright and his wife,[10] which occurred at this time, as it has been told with so many variations.[11]

Thomas Arkwright, Richard's father, had a brother named John,[12] who was married and lived in Preston, but had no children. When he died he left his widow in possession of a handsome fortune; after her death it was divided amongst numerous relatives; Richard's share came to more than £400. This sum he invested in the joint names of his wife and himself. In his financial trouble Richard turned to his wife and appealed to her to agree to the money being invested in the mill; but she, having no confidence in his schemes, refused. He pleaded hard, but she remained adamant. They separated their marital relations for life, yet remained friends, and neither would say, or allow others to say, an unkind word of the other. During the earlier separation, Mrs. Arkwright cared for the children, Richard making her an allowance which was within two years increased to £500 per annum. She lived with her married daughter and survived her husband about twenty years.[13]

It was at this critical period in Arkwright's financial affairs that his bankers, Messrs. Wright, rendered eminent services to the infant cotton industry by introducing Arkwright to Mr. Samuel Need, who was in partnership with Jedediah Strutt, the inventor of the Derby Rib Stocking Loom. Both were successful men of business with ample capital. Need mentioned the matter to his partner, who inspected the mill with the result that a partnership, called Arkwright,

[10]This version was given me by the late Hon. Frederick Strutt.

[11]"A Compendious History of the Cotton Manufacture with a disproval of the claim of Sir Richard Arkwright to the invention of its ingenious machinery," by Richard Guest, 1823, contains evidence bearing out this story.

[12]John Arkwright was churchwarden of St. Peter's Parish Church, Preston, at the time of Richard Arkwright's baptism in 1732, and signs the register.

[13]Arkwright married twice. His first wife was Patience Holt, a Presbyterian, whom he married at Bolton according to the rites of that faith, in 1755. By her he had one son, Richard, baptised at Bolton, Jan. 18th, 1756, by the Rev. Philip Holland, Presbyterian Minister. Patience died October, 1756, and was buried in Bolton Parish Churchyard. His second wife, Margaret Biggins, of Pennington, Leigh, he married by special license at Leigh Parish Church, March 24th, 1761, by whom he had one daughter. (Willersley MSS.)

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Need and Strutt, was arranged between the parties. Need retired soon afterwards and confined himself to the partnership in the hosiery business with Strutt. Then began the celebrated association between Arkwright and Strutt which ran for the agreed term of twelve years. Their first act was to secure protection for the machine. This was granted by patent July 3rd, 1769 (No. 931), and in the clearness of the specification I am inclined to see the wise guidance of Strutt. The story of the building of the Cromford Mill, the pioneer of the factory system has been so often told, I need not pursue that theme.

It is important that we should review Arkwright's invention in detail in order that we may compare it with Paul's patent. Arkwright, following the admirable drawings (Pl. xvii.) affixed to the specification, says:—

"A, the cogg wheel and shaft, which receive their motion from a horse; B, the drum or wheel which turns C, a belt of leather, and gives motion to the whole machine; D, a lead weight which keeps F, the small drum, steady to E, the forcing wheel; G, the shaft of wood which gives motion to the wheel H, and continues it to I, four pair of rollers (the form of which are drawn in the margin), which act by tooth and pinion, made of brass and steel nutt, fixt in two iron plates K. That part of the roller which the cotton runs through is covered with wood, the top roller with leather, and the bottom one fluted, which lets the cotton, etc. through it, and by one pair of rollers moving quicker than the other, draws it finer for twisting, which is performed by the spindles T. K, the two iron plates described above; L, four large bobbins with cotton rovings on, conducted between rollers at the back; M, the four threads carried to the bobbins and spindles, by four small wires fixt across the frame in the slip of wood V; N, iron leavers with small lead weights, hanging to the rollers by pulleys, which keep the rollers close to each other; O, a cross piece of wood to which the leavers are fixed; P, the bobbins and spindles; Q, flyers made of wood, with small wires on the side which lead the thread to the bobbins; R, small worsted bands, put about the whirl of the bobbins, the screwing of which tight or easy causes the bobbins to wind up the thread faster or slower; S, the four whirls of the spindles; T, the four spindles which run in iron plates V, explained in letter M; W, a wooden frame of the whole machine."

With such a clear description we are not left in any doubt as to Arkwright's invention.

It is interesting to observe that Strutt's name does not appear, but Smalley signs as a witness. Strutt never shared with Arkwright in the profits of the patent; thus Arkwright received all the license fees, the patent remaining his sole property, the partnership alone being allowed free license. This patent ran the full term of fourteen years and was never challenged during its period in a Court of Law. The fact of Paul having patented the roller drawing principle in 1738 does not appear to have been known to anyone until about the year 1781, when the patent records were searched in view of the forthcoming trial in respect

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of his second patent, when Arkwright sued infringers and won his suit. It was the result of this trial that brought about the celebrated *Scire Facias* trial of 1785.

The only discoverable similarity between Paul's and Arkwright's specifications is in the wording. Paul merely mentions the bare principle, whereas Arkwright gives the details which make that principle a success. Paul uses two pairs of rollers, though Wyatt mentions four in his notes. Arkwright states he uses four rollers in pairs, the top covered with leather and the bottom fluted, and the series automatically weighted to ensure contact. It is impossible to bring oneself to the conclusion that Paul or Wyatt ever succeeded in anticipating Arkwright or that Arkwright founded his invention on that of Paul. The two patents only agree in one particular, viz., the principle of roller drawing.

I am inclined to think that neither Paul nor Wyatt had what I term "spinning sense," the absence of which is to be found throughout the Wyatt MSS. Wyatt found that plain rollers, with hard surfaces, did not draw, so he tried "covering with leather, cloth or shagg, hair or bristle brushes, points of metal set in wood or fixed in leather and afterwards wound round the rollers which makes it in some measure resemble the face of the common cards." Drawing under such conditions is an impossibility. His suggestion to use leather comes nearer to Arkwright's idea, but, as he follows on with descriptions of totally different materials, it seems he had not realised the importance of resilient leather covering. Further, it it quite possible he had in view hard shoe leather, which is what Highs said he employed, when he gave evidence at the *Scire Facias* trial (see below). Again it is probable that Paul and Wyatt made the rollers with fixed pressure. Had they possessed the spinning sense they would have avoided such combinations.

Arkwright, living at Bolton and Manchester, was in a cotton-spinning atmosphere, and therefore gained the spinning sense. He fluted his bottom rollers and drove them only; the top rollers were covered with soft alum leather, such as was then, and still is, used for making gloves. Such leather was capable of being pared down level and thin. The contact between the top and bottom rollers was maintained by leaden weights, carefully regulated so as to give flexibility and to be capable of almost automatic adjustment. This system remains unaltered to this day. The combination around the principle of roller drawing as invented by Arkwright is the entire secret of his wonderful success.

It is interesting to relate a curious incident, which, like many others associated with Arkwright, has been told and retold with considerable distortion.[14] When the Cromford Mill began operations, there appeared a trouble called "licking," viz., the cotton, instead of being given to the spindle, lapped round the front rollers. In his trouble, Arkwright appealed to Strutt for help to solve the diffi-

[14]The late Hon. Frederick Strutt vouched for the accuracy of this version.

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culty, and he, at once discerning the cause, took a piece of chalk from his pocket and chalked the front top rollers, when the licking ceased. The atmosphere at Cromford being damp, the alum-tawed leather absorbed the moisture, hence the licking. The method of covering the top rollers by Arkwright may be seen on his machines in the Science Museum, South Kensington; it comprises a curious and neat form of sewing.

In the life-size painting of Arkwright by Wright, at Willersley, the beautiful residence built by Arkwright in the Vale of Cromford, he is seen seated alongside a table on which reposes a head of rollers. The front top rollers are red or brown, and the three back top rollers are white alum leather. The front top rollers are evidently covered with bark-tanned sheep leather, much as they are to-day, and this change doubtless arose through the licking difficulty. Alum-tawed leather continued to be used until recent times in Scotland, but its employment has, I believe, now finally ceased.

In 1775 Arkwright took out a patent (No. 1111) mainly intended to protect his carding-engine. Six years later he sued a number of infringers of this patent and won his suit. This result set all the spinners in alarm, and in their anxiety they appealed to the Government to have the decision set aside. This was accomplished by Writ of *Scire Facias* in 1785; His Majesty's Attorney General being the plaintiff. This action definitely set aside the 1775 patent. Whatever may be said of that trial, everyone agrees that we owe the present continuous carding-engine of to-day to the inventive ability of Richard Arkwright. The principles involved therein remain with us, though detailed improvements have been introduced as the result of general experience.

It is from the report of this trial that we learn something of the claim of Thomas Highs to the invention of roller drawing, and his evidence is worth retailing.

Of the man himself we have been able to learn little. He was a native of Leigh, near Bolton-le-Moors, and by trade a reed-maker. His evidence at the *Scire Facias* trial of 1785, so far as it is material, is as follows:—

Mr. Serjeant Bolton: Look at the rollers through which the thread comes, the roving or spinning, or whatever it is called. Did you ever see rollers like those before 1775, before Mr. Arkwright's patent?

(It will be noted that Sergeant Bolton refers to Arkwright's patent of 1769 as though it was part of the 1775 patent under trial.—A.S.J.)

A. I have seen rollers; I made rollers myself in 1767.

Q. You see one is fluted, the other covered with leather.

A. I see it is.

Q. Was yours the same way?

A. Yes, mine was, *two years after, but not then.*

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Q. Not at first?

A. No.

Q. In 1769 yours were like it?

A. They were, mine had fluted work, fluted wood, upon an iron axis; but the other roller was the same, only it was covered with shoe leather, instead of that leather; I am informed it is such as they make shoes of.

If Highs' evidence is to be relied on, it follows that he and Arkwright had been working on the solution of the mechanical spinning problem at the same time and contiguous to, though, as I think, unknown to one another.

John Kay, who was for some time in Arkwright's employment but was dismissed for theft, gave evidence which is worth quoting:—

Q. Before you go further, who did you get the method of making these models from?

A. From Mr. Highs, the last witness.

Q. Did you tell Mr. Arkwright so?

A. I told him; I said another man had tried that method at Warrington. (Highs had stated in evidence, "I employed one Kay, who came from Warrington.")

Q. Look at that, was that the sort of model, or was it at all like that?

A. It was with rollers.

Q. It was with double rollers in that way?

A. Yes, with four pairs of rollers; this has only two.

Q. Were they fluted?

A. No.

Q. Neither of them?

A. No.

Q. Neither top nor bottom?

A. No.

In face of Highs' admission, that he never employed the essentials in Arkwright's system until two years after Arkwright invented it and was operating the system commercially, and Kay's damaging confession that he did not make the model for Arkwright with fluted rollers, Highs' claims must be dismissed as those of a dreamer.

Arkwright accumulated great wealth, and he is said to have offered to finance the Government of that day in its wars, provided it would continue to him his patented rights for a number of years. He became High Sheriff of Derbyshire, and was knighted by King George III. He died in 1792, aged 60, and was buried in the pretty church at Cromford which he built.

Looking backward, I cannot but think that Arkwright was fortunate in having as his associate and partner such a fine type of English gentleman, of such high moral standing and sound common sense, as Jedediah Strutt. It would, almost,

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seem as though he moulded his behaviour and demeanour on that of his partner, with the result that Arkwright was admired and honoured by all who became associated with him in his works. The two men were opposites in religion and politics; Strutt was a Unitarian and a Radical, whereas Arkwright was a Churchman and a Tory. Yet both remained life-long friends, and the families have continued that friendship to this day.

Mr. Seymour-Jones remarked that his paper was to have been read in April, but had been postponed owing to the coal crisis. One advantage had resulted from the postponement—the paper was being presented in the City in which the invention of roller spinning had its birth, and in the Library that possessed the Wyatt MSS. which contained what evidence there was on Wyatt and Paul's share in the invention of drawing by rollers.

The author gave only a brief epitome of his paper, prefacing it by a description of the preparation of cotton fibre and of hand spinning.

He exhibited a photogravure of the Wright portrait of Arkwright, a facsimile of one of Arkwright's letters, and a number of photographs connected with his life and work.

DISCUSSION.

The discussion was taken part in by Mr. Brownlie, who moved a vote of thanks to the author, Mr. Hulme, who seconded, Mr. Pendred, Mr. Welffens, Mr. Powell, Mr. Jenkins and the Hon. Secretary. The consensus of opinion was that Paul and Arkwright were both original and both deserving of credit, but the latter had the credit of having established an industry of vast importance. Mr. Welffens advanced the theory that Paul had been trying to spin cotton waste, and gave up drawing rollers after trial as too difficult and too expensive. The author, replying, did not agree; his contention was that Paul had failed because he used sole leather, which was useless, whereas Arkwright used alum-tawed leather, and discovered the right way to put it on the rollers.

The vote of thanks was carried by acclamation, and at the close of the meeting Members spent an hour inspecting the Wyatt MSS. and a number of books, belonging to the Library, treating of the history of cotton manufacture. The Boulton and Watt Collection also came in for study.

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Appendix.

Transcript of

HOLOGRAPH LETTER

RICHARD ARKWRIGHT TO JEDEDIAH STRUTT.

Cromford Marh 2d 72.

Sir,

Yours yisterday came to hand together with a bill from Mr. Need Value 60lb (i.e. £60). I have sent a little cotton spun on the one spindle & find no Difficanty in geting it from the Bobbin & Dubeld & Twistd in the maner you see it at one opration. One hand (i.e. workman) I think will do 40 or 50lb. of it in one day from the bobins it is spun upon, that is in the new whay. I am sertain of it ansuaring & one person will spin a Thousand Hanks a Day so that wee shall not want 1/5 of the hands I First expectd notwithstanding the Roaveing takeing so few. I see greate Improvements every day. When I rote to you last [I] had not thorowly provd the spining; several things apening I could not acount for sinse then has proved it—I have made trial to twist it for Velverets & find what the[y] do with five operations [I] can do with one that is duble & twist it Redey for wharping at one time; first they reel, second wind, third Duble, fourth twist, 5 wind redey to wharp, & all these done one thred at a time except Twisting. [I] shold like you [to] try a little of this hard [yarn] in a ribd fraim; I think it shold not be whet but beate. Plais to send the solft [i.e. soft yarn] to Mr. Need. One has a slacker throw then the other, naither of [them] perfect but [I] shold like to see a stockin or part of one; pray Bring a Little with you. Mr. Need spakes of wanting Thos Bell & a turner but [I] cant see what they whant Thos for. I spok to Coniah & dar say he will com if he was properly aployd to or they might get a man from Hibisons but there is no person at the mill that will put themselves out of their way to be of aney servis Except teas(e) Mr. Needs hart out with a continual want & uneasiness. As to sending aney hand from hear I cant think of doing [so], for where they get a shiling cleair there shall [be] in a few months 40, I am posative. If Mr. Need thinks best [I] can go one or two days pr. wheek to Nottingham & shall shortly suply them with Roaveings from hear if wee cant spin 2000 Hanks a Day which I am sertain I can in four months at the out side, and now as solfter [i.e. softer yarn] can be spun faster than hard, stocking yarn will ansuar best & will be Dubled with very little expence. At the mill the[y] whant Cards puting on. Andrew might do that as it requiers no greate judgement, but I sopose he is a deal taken up in those Looms & the profits of wich will scairsly pay wharehouse room. If he can be got to wheave by the

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Pees [i.e. piece] or yard & out of the mill, [I] shold sune set that plase in Better order but while he is in it is scairsly posable. Except he has his own whay no good will be don with justis or him, & what I sade to George is what I shold say again: it whas unraisenable. In a few weeks [I] shall move for wee can do without them all. It is onley seting another pair of cards &c; hear wee have begun of them. [I] shold like to know if aney acount as come from Hallifax lately; he has sent som other cards but not the quantety I Rote for and no Letter or bill with them. [I] shold [have] Rote to Mr. N. but has not time & wold [like] when I do send to send some twe [i.e. two] threds, solft and as even as silk. I am sertain I can [make] the first fraim; I have hands to make three frames in a fortnet. It shall be don you may depend upon it, but I whant sombody to look after the spining &c. I have rote to Kay yesterday; if he will not come can you think of sombody? A yonge man was hear this wheek sade he had spoke to you; this is his Riteing I send Inclosed. What do you think of him? He seemes a likely person but has all to lern. I am afraide no one man will know all that I should expect the[y] might. Rich[d] has hit upon a method to spin woostid with Roulers; it is quite sertain, & only altering the shape—that is Round on one side and flat on the other—so that the twist gets under or betwixt them at sertain time[s], it will ansuar I am sertain. Query: will not Cotton make whipcoard as good as silk, properly Twisted? It may be don all at onst from the bobins. Pray Rite to Mr. N. what he thinks best. I cant think of stoping this Concern hear as that at Nottingm. is (not) or Ever will be aneything in comparison to this. There is hands to be got there & if he wold have mee com over I shall, but not take aney hands from hear. I ask[d] Mr. Whard to get some Let [? lead] pipes to bring the water into the mill; they are coninuially [i.e. continually] fetching. It might be brought in the Rooms. Wold it not be best to fix a Crank to ore [one] of the lying (?) shafts to work a pump or Ingon in case of fire? Bring the belts with you. Desire Ward to send those other Locks and allso some sorts of Hangins for the sashes he & you may think best and some good Latches & Catches for the out doors and a few for the inner ons allso and a Large Knoker or a Bell to First door. I am Determind for the feuter to let no persons in to look at the wors [?works] except spining. The man Mr. Whard Bot the ash Board from call[d] for his money & says he will send the other shortly. I am tired with riteing so long a letter & think you can scairsley Reed it. Excuse haist

and am yours &c

R. ARKWRIGHT.

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Presidential Address

by Arthur Titley.

(Delivered at Queen's College Chambers, Birmingham, June 16th, 1921.)

In thanking you for the compliment you have paid me in electing me your first President, I find myself in the happy position of having assisted at the successful launching of a venture which it has long been my hope to see under way. As an engineer I have always considered it a reproach both to the engineer and the historian that the systematic study of the history of engineering has so long been neglected.

The fact is, the engineer has always devoted his energies to the advancement of his craft and science. He has long been conspicuously on the crest of the tide of civilisation, and has been too busily engaged to indulge to any extent in retrospect. The historian, on the other hand, has usually devoted himself to other aspects of human affairs, and with few exceptions has left industry severely alone. Samuel Smiles, in his "Industrial Biography," quotes an eminent mechanic of his days as saying:—"Kings, warriors, and statesmen have hitherto monopolised not only the pages of history, but almost those of biography...I do not begrudge destructive heroes their fame, but the constructive ones ought not to be forgotten."

As a nation we are not inclined to take the lessons of history to heart. We are in the habit of looking ahead, of giving to our own generation the credit for all that we find good in the present, and of referring all that we consider bad to the days of our forefathers. And this seems always to have been a national characteristic. Lord Bacon said, referring to the slow progress of the arts, "that we were too apt to pass those ladders by which they had been reared, and reflect the whole merit on the last new performer." There are, however, a good many exceptions to this rule, and it seems strange that no attempt has hitherto been made to bring together those who appreciate the interest and value of the study of this branch of history.

I was much struck on the occasion of the Watt Centenary Meeting in Birmingham in 1919 with the strong undercurrent of interest shown by many gentlemen present in all phases of engineering history, beyond the immediate object of the meeting, and any doubts I may have had as to the possibility of forming a society of this kind were dispelled directly I came into contact with several of their number who are now among our members. The result of our conversations was that a meeting was held in Birmingham, followed by one in London, at which the idea was cordially received.

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Since the inception of our Society it has been agreed that it should take a wider purview than merely of the work of the engineer; indeed it could hardly be otherwise. The engineer is the servant of industry, and it is largely by his assistance that industry effects its objects. Engineering is surely one of the hardest words in the dictionary to define. The historical work that has already been done in industrial subjects has been principally due to individuals, who have sought under the greatest difficulties for the information which they needed. We propose for the first time to carry on this work by a system of mutual help and co-operation. We hope as our aims become known to attract to our ranks all those who have already interested themselves in industrial history, and to stimulate that interest in others. We feel assured that every trade and every manufacture has its student of history, and we trust that we have founded a Society that shall be of real use to him, and to which he in turn will be willing to give his help.

We have recognised from the first that we were a Society whose aims were new, and which had no precedents for its guidance. We have, therefore, deferred any complete consideration of its constitution till our membership could be said to be well representative of historical interests in our particular field. We therefore appointed officers and a committee to carry on the preliminary work of the Society till we were in a position to appreciate our requirements more fully. Our first year's development has been such that we must soon consider our organisation more completely, and we propose to hold a general meeting for this purpose early in the next session. We are very much indebted to Mr. H. W. Dickinson for undertaking the duties of honorary secretary and treasurer during this initial stage. No one is in a better position to understand our needs or to assist us in the development of our aims.

The Name and Aims of the Society.

The choice of a name for the Society presented considerable difficulty. We were very anxious to select a name that should be appropriate and which should express our objects in the fewest words. After many attempts and a prolonged discussion at the London meeting we were still dissatisfied. The meeting eventually referred the matter to the committee, and a special committee meeting was held to consider it further. It was then suggested that to chose a short and handy name with a descriptive sub-title would be better than attemping to select one that was descriptive in itself. We accordingly agreed to identify ourselves with the name of Thomas Newcomen, the man who first drove a piston through the agency of steam, as typical of the great industrial movement commencing with the early years of the eighteenth century, which owed so much to the coming of the steam engine. The aims of the Society have been clearly set forth in the circular which is in the hands of its members. In order to fulfil these aims it is necessary that every member should feel that he is in actual touch with his fellows and that the Society is really the medium for the exchange of ideas and

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information which we hope to make it. Our membership, we believe, will be widely distributed geographically, and a good deal more than the reading of papers at meetings will be needed to maintain that touch. If members will state the subjects in which they are interested and in which they seek or are able to give information, the Society can at once commence to perform one of its most important functions. We hope shortly to publish our proceedings in the form of a journal or year-book, believing that this will be of vital importance in ensuring the success of the Society.

Our membership at present numbers ninety and is of a promisingly representative character, embracing manufactures, professional and industrial engineering, technical literature and education, and the technical press. Among the names of our members we welcome the historic ones of Savery, Newcomen, and Trevithick. Besides those in the London district we have members in Essex, Surrey, Kent, the Isle of Wight, Devon and Cornwall, Gloucestershire, Cambridgeshire, Lincolnshire, Warwickshire, Shropshire, Nottinghamshire, Northamptonshire, Lancashire, Yorkshire, North and South Wales, Scotland, in Winterthur, Berlin, and in New York. Although our Society is a pioneer one, we are not merely an association of ambitious amateurs. Many of our members have published critical work upon subjects coming within our view, and this places us at once in the position of a responsible association.

The variety of subjects in which we are interested is already considerable. It embraces the engineering of the ancients, the mechanics of Aristotle and his school, iron and steel manufacture, brass making, copper smelting, glass making, mining and metallurgy, gun making, ironfounding, spinning, the alum industry, wind and water mills and millwrighting, rolling and slitting mills, the motor car, early waterworks, papermaking, the early steam engine, and the locomotive. Under the head of biography the life and work of the following pioneers have engaged our attention:—Sorocold, Dud Dudley, Worcester, Savery and Newcomen, Boulton and Watt, Sir Samuel Morland, Smeaton, Symington, Richard Trevithick, the Hornblowers, Arthur Woolf, McNaught, George Heaton, Joseph Hall, John Wilkinson, and Robert Fulton.

The more one contemplates the objects we have set forth to attain the wider the field appears. Not that this need discourage us. It rather offers greater scope for the taste of the individual. Besides, the wider our studies are extended the greater is the number of facts we may hope to bring to light, for anyone who has indulged in the fascinating but exasperating occupation of delving into past records knows only too well the difficulty of tracing an elusive fact to its origin and of avoiding false scents and unproductive by-ways. It is here that the system of mutual assistance through the exchange of references which we propose to inaugurate should be of the greatest value, for in our reading we often come across stray facts quite wide of the subject in hand which may be just what another worker may have been seeking for years.

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In our first session we have heard five papers read and discussed. The first of these was Mr. Hulme's very useful contribution: "An Introduction to the Literature of Historical Engineering to the Year 1640," which was a very appropriate subject with which to open our proceedings. I fancy that a good many of our members may be in the same position as myself as regards the literature of our subjects. They may have an intimate acquaintance with a limited number of books, old fireside friends perhaps, but may not be in the position to be able to appraise them at their true historical value. I hope we may hear other papers on books from those members who can amplify our knowledge. We know, for instance, that much of the literature on the early history of the steam engine is very unreliable, and a critical summary of the historical value of such literature would be of great assistance to students in the particular field to which it applies. Mr. Pendred, in his paper on "The Mystery of Trevithick's London Locomotives," gave us as far as his subject permitted him just the kind of criticism that would be most useful to us. We have also had from Mr. Rhys Jenkins the two papers on "The Sussex Iron Industry," which, I think I may say, have given us a stimulus and an example to live up to, in the complete investigation of the subject that he has carried out. Mr. Seymour-Jones, too, in his paper on "Roller Spinning," has given us another excellent example of what the Society can do in the elucidation of an obscure piece of industrial history. Useful discussions have followed the reading of all these papers. Altogether I think we may be congratulated on the first year's work of the Society, and we hope that members will come forward with more papers still in the next session. It is not necessary that we should wait till we are in a position to give a paper which is a complete monograph on a particular subject. Short papers giving notes on any matter that members may have in hand will be useful and tend to elicit further details in discussion. The paper which Mr. Haines and myself have prepared but which we shall not have an opportunity to read in full at this meeting is of this character. It is merely intended to show the great amount of work that remains to be, and can be, done on the interesting subject of the country mill and early millwrighting, both from books and from existing examples, which are far more numerous than a casual knowledge would lead one to think.

Educational Value of History.

Of the practical value of our work I think there is a good deal to be said. There appears to have been very little effort made to use the history of industrial progress for educational purposes. Yet it should surely have a place in our system of technical education, and, judging from recent references to the subject in the technical press and elsewhere, the idea would seem to be gaining ground. In reading old engineering works or studying old drawings, one very often comes across processes, machines or details of machines, and methods of construction which have dropped out of use—apparently for no reason. They seem to have been

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forgotten and could often be modified and applied to modern requirements with advantage. The designer and the inventor can learn much from history, both as to what to make use of as well as what to avoid. A good example of the suggestive study of history can be given in John Ridley's invention of the stripper for harvesting grain in countries where the straw has no commercial value. Pliny described the use in ancient Gaul of a cart to which an ox was harnessed in the reverse direction to the usual one. On the back of the cart, which was thus the advancing end, were attached comb-like projections. These caught the straw just under the ears, and the reaper then cut them off and they fell into the cart. Ridley, remembering this, devised a machine which automatically stripped off the ears, and added a thresher and winnower, so that at one process the grain was collected ready for dispatch. A phenomenal wheat crop in Australia was thus harvested at a cost of 3½d. per bushel instead of 2s. as previously. Many machines, too, have been used in manufacturing processes for generations, and such machines are usually well worthy of close study, for they have passed through a gradual evolution and are the result of very practical experience of how to arrive at a desired end in the simplest way. We sometimes see machines, too, supposed to be improvements on past practice, that have gone to the scrap heap simply because the experience of previous generations has been ignored.

In my own experience I have always found historical knowledge to be of considerable use. If we can follow up the growth of a process or system from its earliest beginnings to its final development, we are led on to a complete knowledge by easy stages. For instance, take such a process as corn milling. If we enter a modern mill with its rows of grinding rollers, its many scalpers, purifiers, and cleaning machines, and all its confusion of conveyors, elevators and shoots, it is hard, if we are strange to the system, to grasp the meaning of it all. But first enter, in imagination, the simple country mill so well known to Chaucer and watch with his two clerks of Cambridge its elementary machinery at work—

> ..... " right by the hopur wil I stande,"
> Quod John, " and se how that the corn gas in,
> Yet saugh I nevere, by my fader kyn,
> How that the hopur wagges til and fra."

and then study the work of Smeaton, Rennie, and Fairbairn, and the later mysteries of high grinding and purifying methods, and the subject becomes clear and consecutive.

There is more of tradition in engineering than we are in the habit of admitting. We are daily using details and methods that were originated by the great mechanics of our forefathers' days; it is our part to give them credit wherever we are able to detect their hand. While referring to the value of a knowledge of industrial history I should like to say that the great work done by the past

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and present authorities of the Science Museum at South Kensington is a notable exception to the general neglect of our branch of history. I have often been struck by the want of knowledge among engineers and others of the wonderful collection of relics and records and of the beautiful historical models that are there brought together and made available for our study. We hope to visit the Museum early in our next session.

In olden times the growth of industries was slow. To-day it is proceeding in many directions at a great pace. The windmill and the water-mill took perhaps a thousand years to develop to the condition in which they are still to be found. The atmospheric engine originated a little over two hundred years ago, and may now be said to have disappeared. The motor car had its beginnings before the end of the eighteenth century, but the internal combustion engine, the telegraph and telephone and the wireless telegraph, and the whole enormous field of electrical engineering are practically things of our own day. Many of the facts relating to their history are disappearing daily before our eyes, and unless we seize upon them and preserve them they will be lost for ever. Our Society can do good work in obtaining records from living men who are engaged in these and similar developments while there is yet time. It may be said, considering the little care that has always been taken to preserve records of industrial history, that the prospects of recovering facts and filling in the gaps is small. Apart from the interest of the search, however, it must be remembered that there is always the prospect of a find to lead the enthusiast on, and that the recovery of one small link often connects up the labours of several previous workers. Farey and Stuart, Tredgold and Galloway, and a host of other writers up to 1876, were quite in the dark as to many details of the atmospheric engine in its early days. The almost dramatic appearance of the Barney print threw a flood of light upon the subject. The production at our meeting on the occasion of the reading of Mr. Pendred's paper of the Rowlandson drawing, rescued from oblivion by Mr. Levis, and of a new Trevithick model, may be taken as a good omen. These may yet prove to be links in the chain of evidence needed to clear up a very doubtful piece of locomotive history.

Even in the greatest of archæological finds the element of doubt has been prominent. It is said that Schliemann was led to choose the locality for his first operations by tradition, in face of the consensus of antiquarian opinion. Nevertheless, he discovered the superimposed remains of three cities and laid open the evidence of the existence of forgotten civilisations enough to provide his critics with food for argument for several generations. Occasionally one comes across a minor find which throws a light at the same time upon an obscure piece of history and upon the characters of individuals. I will quote one, for which I am indebted to Mr. Jenkins, in reference to Richard Trevithick. It is known

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that when Trevithick was a young man, building and running pumping engines in competition with Watt and his fellow Cornishmen, Boulton and Watt obtained an injunction to restrain Trevithick from infringing their patent. A letter from Matthew Boulton to Wilson, their agent in Cornwall, for the first time shows how the Cornishmen had stood to their motto of "One and all" in preventing the serving of the injunction. The episode I am about to relate occurred immediately after Boulton and Watt had succeeded in their suit against Hornblower and Maberley. Boulton wrote under date of December 26th, 1796:—"Woodward found Trevithick and his Friends at a publick house facing my Manufactory and delivered to him ye injunction, which he received with much surprise, particularly as he thought nobody knew him. He seemed much aggitated and vexed; however, he afterwards went with Bull and Andrew Vivian to dine with Simon at the Foundry, where he found our men firing of cannons and rejoicing of our Victory which took away his appetite from his dinner. Andrew was admitted to the Foundry and Manufactory but not the others. It is rather curious that although ye injunction could not be served in Cornwall, T. should run into the Lyon's Mouth and afterwards go to Dine with the man they had Banished from Cornwall. They went to Colebrookdale, but know not their reception." Letters from J. Southern to Boulton and Watt juniors in London throw further light on the episode:—"After Trevithick had been served with the injunction, the circumstances of which you will be acquainted with, he and Bull went to Vivian's at the Foundry, where Forman and A. Vivian were dining. Bull took his dinner quietly, but Trevithick walked backwards and forwards in the house like a mad man, and firmly resisted all temptation to dinner, till the smell of a hot pye overcame his powers, on which he set to, and did pretty handsomely, but in such a manner as showed he was not quiet in mind. The rejoicing that was going forward at the very door, exhibited by fires and gunpowder work not a little contributed to his *happiness* while he stayed, which was for a very short time indeed. They posted off towards Coalbrookdale."

"I forgot to mention in my yesterday's letter that neither Bull nor Trevithick had any view of the Foundry except what was to be seen from outside the walls, and Vivian's view was hasty; Mr. Forman was with him and them all the time they were on the premises."

It seems strange that with the exception of Westminster Abbey, where there is now an imposing group of windows dedicated to the memory of great engineers, we see little public acknowledgement of the debt we owe to our industrial pioneers. The monument which was erected to John Wilkinson in the material to which the labours of his life were devoted has now been saved from destruction. At one time it narrowly escaped being removed to Germany, where his reputation as a pioneer of the iron industry was better appreciated than it was in his own country. The memorial tablet that was placed by the enterprise

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of a private individual in a church at Dartford to record Trevithick's burial place and the fine statue which is to be erected to his memory at Camborne, are examples that might well be followed.[1] In the streets of Birmingham we have an excellent statue of James Watt, but no public memorial to his illustrious partner arrests the eye of the passer-by in our public places. Our Society can do good work in encouraging the erection and preservation of such monuments.

The Development of Handicrafts.

The vast number of subjects that lie before the Society is sufficiently apparent, and these subjects will meet and overlap in many directions. There are secondary subjects that are more or less common to the whole, and I should like to refer to some of these by-ways which seem to me to be worthy of exploration. One of the chief of them is the development of handicrafts. Out of the more ancient crafts of the blacksmith and carpenter the art of the millwright was evolved through many centuries. The moulder and the patternmaker came upon the scene much later, and their trades developed more quickly. These combined forces may be said to have originated what we now call mechanical engineering, the requirements of which gave birth in turn to the handicraft of the fitter, which was developed in a remarkably short time. The machine tool at first assisted the millwright and fitter, but at last was the cause of their decadence; and these crafts as they were understood by such men as Rennie and Fairbairn are hardly to be found to-day. The possibilities of construction and even of invention were largely influenced by the existing means of carrying ideas into effect, and this reaction between hand and brain can be traced through the work of the engineer to the present day. I think that, apart from the history of an industry itself, a study of the growth of its workmanship and of the tools employed therein would well repay the trouble of investigation.

Our city of Birmingham should offer plenty of scope for the study of the development of handicrafts. Leland in 1538 found the town full of "smiths and cutlers making knives and all manner of cutting tools, as well as lorimers who make bittes." Robert Porter refused to supply King Charles with swords, but made 15,000 for the Parliamentarians, and had his blade mill destroyed for his trouble. From such beginnings grew the many trades that flourished during the eighteenth century in Birmingham, described by Edmund Burke as the "great toyshop of Europe."[2] The steel toy trade in that century is said to have employed half the inhabitants of the town. For more than a hundred years this trade held its own, and all kinds of articles in iron and steel, from buckles and

[1] Newcomen Memorial.—A memorial to Thomas Newcomen (b. 1663, d. 1729), inventor of the atmospheric steam engine, was unveiled at the New Ground, Dartmouth, his native place, on July 21st, 1921. The Newcomen Society took the opportunity of laying a wreath at the foot of the monument—being represented for the occasion by Eng. Comm. E. C. Smith, O.B.E., R.N., Member.

[2] Aris' Birmingham Gazette, March 21st, 1773, p. 3.

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candle snuffers to nutcrackers and jew's harps, were made here. Other curious articles, too, we read of: handcuffs, manacles, leg irons, suits of chains for the Brazilian slave ships, tomahawks for North American Indians, and housebreakers' tools are among the number. Even as late as 1849 a Birmingham firm executed an order for a dozen thumb screws, which were sent to a South American State.

It is not surprising that with the presence of the gun and other highly skilled trades, Newcomen and Watt should have sought the services of the mechanics of our district to carry out their ideas, and so laid the foundation of modern mechanical engineering. The eighteenth century millwright produced his work largely by the use of the hammer and the axe. The modern mechanic uses micrometer gauges and laughs at thousandths of an inch. The labours of many men for over a hundred years have gone to bring this about, but a comparative history of their share in the work, I believe, remains to be written. Even the study of the growth, duration, and disappearance of workshop and technical terms would throw light on the history of an industry, and should prove an interesting subject to those philologically inclined.

I expect most of us have been struck by the high development of mechanical drawing about the beginning of the nineteenth century. The really beautiful drawings of Clement and Farey, as expressed by the fine engravings of Lowry and others, are particularly striking, and it would almost seem that mechanical illustration had reached its highest point at that time. That photographic processes of reproduction have done much to check later development modern works on engineering clearly show.

The influence of the early engineering works in training engineers is I think, another good subject. Soho Foundry, Bramah's, Maudslay's, and Hayle sent their skilled mechanics all the world over, and many more old works might be added to the list. The early locomotive shops, too, trained men with traditions especially their own, while in our own day the interaction between the older style of engineering and the cycle, motor, and electrical trades is still influencing the character of the engineer and the mechanic.

Concurrently with the growth of an industry and its craftsmanship there arise what I may perhaps be permitted to term its canons of art. If we observe an early machine in the first clumsy form that genius gave it and follow out its history, we see that it improves with the mere development of the experience and the workmanship put into it. But besides this, as its construction becomes familiar, its originally crude form becomes softened down by the man who appreciates proportion, fitness, and outline—in other words, the artist. We see this in the Cornish pumping engine, the locomotive, the planing machine; in fact, in any machine that has passed through an evolutionary period. I do not know that anything has been written on this subject, but it appears to me to be important in assigning the proper place to those men who have made mechanical engineering

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what it is. Nasmyth, I think, had it in view when he wrote of Henry Maudslay, "that you could see the man's character in whatever work he turned out; and as the connoisseur in Art will exclaim at sight of a picture, 'That is Turner' or 'That is Stansfield,' detecting the hand of the master in it, so the experienced mechanician, at sight of one of his machines or engines, will be equally ready to exclaim, 'That is Maudslay.'"

Biography.

Personally, I am looking forward with a great deal of interest to the biographical side of the Society's labours. The pioneers of all times have been men of great originality and force of character. To know them intimately, to learn their mentality and their methods of work, is to appreciate their individuality and to be able to trace its influence long after their names have been generally forgotten. Even the lightest anecdote relating to them which may be retrieved from the lumber of the past may serve to throw a light on their careers and on their influence upon the march of civilisation. This knowledge of character helps us in calling up a mental picture of the man and assists us to form a correct value of the work he did. Thus we may look back to that most mediæval of men, Edward Somerset, second Marquis of Worcester, of whose character, by the way, we know a great deal more than we do of his mysterious pump. We may see him, before he became involved in the vortex of the Cromwellian wars, explaining his inventions to "that most unparalleled workman, both for trust and skill, Caspar Kaltoff," with "a prolixity of speech and a natural defect of utterance," to which he himself pleads guilty. We may see that almost illiterate man, James Brindley, his originality quite unspoiled by the modern crystallising influence of specialisation, setting forth, axe on shoulder, to fell the tree that is to form the shaft of the water-wheel that his ponderous brain has conceived. We may sympathetically follow his abortive attempt to make his wooden-cylindered steam engine go, and afterwards read the remorseful entry in his diary, "to run about a-drinking 1/6d.," and we feel that we know James Brindley.

We see Smeaton, the father of the civil engineer's profession, improving everything he touches, and carrying out his beautiful experiments with apparatus made by his own hand, in which he first taught engineers to go direct to Nature for their knowledge. We may read his "Reports," full of thought and scrupulous care, to study which is in itself an education, and we put them down with a profound respect for the abilities and the absolute integrity of the man. We may see Murdoch and his fellows, lurking, as it were, in the shadows of their great masters, building up the traditions of one of the greatest schools of engineers and mechanics that the world has ever seen. We may contrast the characters of those two great rivals, Watt and Trevithick. Watt, the retiring philosopher, working out his inventions with deliberate care and finish. The buoyant and irrepressible Trevithick, never at a loss for an idea or a detail, covering the whole field of

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steam engineering in a fever of genius, and extending that field far beyond the limits of vision of his own generation. We may follow the career of the one, led almost against his will, by the "princely Boulton" to affluence and a venerated old age; or that of the other, through a romantic maze of lifelong activity, to a pauper's grave. There is a dignified passage in one of Trevithick's last letters that gives one of those flashes of illumination which are the occasional reward of the student of character in biography:—"This so far has been my reward from the public; but should this be all, I shall be satisfied by the great secret pleasure and laudable pride that I feel in my own breast, from having been the instrument of bringing forward and maturing new principles and new arrangements, of boundless value to my country. However much I may be straitened in pecuniary circumstances, the great honour of being a useful subject can never be taken from me, which to me far exceeds riches."

DISCUSSION.

Mr. Hulme, moving a vote of thanks to the President, said that the address was marked by literary ability and historical knowledge. He was pleased to note that philology was not excluded from its purview, because it was useful in elucidating the origin of trade terms, and hence that of industry itself; trade customs were equally important. He gave instances, derived from several languages, of terms that required explanation.

Mr. Pendred, seconding the vote of thanks, said the address appealed to him greatly. He believed people could get as true education from the study of industrial inventions as from that of history as ordinarily taught. He laid stress on the refining influence of the history of science and invention. Draper and Buckle had traced the history of civilization, but had not paid due attention to industrial development. He would draw attention to the good start that the Society had made in bringing to light objects of interest in the history of engineering.

The discussion was carried on by Mr. Jenkins, the Hon. Secretary, Mr. Rowatt, Mr. Greener, and Lt.-Col. Foster.

During the evening, the following gentlemen exhibited objects that are placed beneath their names:—

W. H. Dugard, Member:

Original drawing of road locomotive, by George Heaton, 1826.

Heaton's quadricycle, with motions as in the above.

Heaton's model illustrating the balancing of locomotives.

Sir Gerald Chadwyck-Healey, Bart.:

Engineers' scrap book, 18th to 19th century, formerly the property of William Reynolds of Coalbrookdale.[1]

[1]It is understood that this book will eventually be presented to the Science Museum, South Kensington.

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C. E. Greener, Member:
Two examples of smoke jacks.
A. Titley, President:
Drawings of Chesterton Windmill.
Nigerian brasswork and ironwork; Kaffir pipe—to illustrate modern primitive work.
E. B. Martin, Member:
Original drawings of millwork, 18th century.
Old books bearing on millwork.

SUMMER MEETING AT BIRMINGHAM.

June 16th & 17th, 1921.

In addition to the reading of the paper by Mr. A. Seymour Jones and the delivery of the Presidential Address, a number of places of interest were visited. The excursions on the first day were to Messrs. Heaton & Dugard's Rolling Mills at Shadwell Street. Here the button-shank or chain machines, Ralph Heaton's invention patented in 1794, and the compounded beam rolling mill engine, attracted much attention.

The party then visited, by permission of Mr. Willett, the engineer to the Birmingham Canal Navigations, the Watt pumping engine of 1812 at Lawley Street, used for maintaining the water level of the Canal there.

Proceeding to Bordesley, the party were shown over the Watt pumping engine of 1795, disused since 1884, by Mr. James-Carrington, Member, in the absence of Mr. Wm. Salt, engineer to the Birmingham & Warwick Canal. The engine which now performs the duty was also inspected.

On the second day, June 17th, the first visit was to Winfield's Rolling Mills, Cambridge Street, where, under the guidance of Mr. W. H. Dugard, Member, and Mr. Chas. Bamford, the party was shown a good example of the beam engine of the early 19th century.

The Corporation Art Gallery, Victoria Square, was next visited, to hear an interesting talk by Mr. C. E. Greener, Member, on the collection of arms there, from the crossbow to the latest sporting gun. The original hank of cotton spun by Paul and Wyatt in 1742 at the Upper Priory Mill, Birmingham, was also inspected.

The party left in time to catch the 12.42 p.m. train to Leamington Spa, where lunch was partaken of before motoring out, under the guidance of the President and Mr. H. D. Haines, Member, to the disused 17th century Chesterton windmill. The millwright work was considered to date from 1775, and was minutely examined.

A further run by the motor charabanc brought the party to Harbury Mill; the millwright work here dates from the early 19th century, but is now, too, disused, its place being taken by an oil engine.

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The Newcomen Society.

FOR THE STUDY OF THE HISTORY OF ENGINEERING AND TECHNOLOGY.

Constitution and Rules.

(*Adopted at a Special General Meeting, November* 16th, 1921.)

I. The name of the Society shall be the Newcomen Society for the Study of the History of Engineering and Technology.

II. The object of the Society is to encourage and foster the study of the history of engineering and industrial technology. Stated in greater detail, it is:—

(1) To disseminate historical information among its Members by meetings, intercourse, discussion, correspondence, circulation of notes and papers, and visits to objects and places of interest.

(2) To act as a channel of communication between Members who are engaged on similar lines of research or study; to indicate as far as possible where information is to be found.

(3) To collect and preserve or cause to be preserved, locally or nationally, examples, records, MSS., drawings and illustrations of, or relating to engineering work and industrial processes.

(4) To collect and preserve in a similar way biographical matter concerning men who have contributed to engineering or industrial progress.

(5) To publish from time to time, a Volume containing original papers by Members, bibliographical notes and historical material not generally accessible.

(6) To form by collaboration among its Members a Card Index of published information on the historical aspect of engineering and technology.

(7) To do all such acts as shall lead to active corporate life of the Society.

III. Membership shall be open to all persons approved by the Council, irrespective of nationality or sex, who have at heart the furtherance of the objects defined above.

Libraries and Institutions may join the Society as subscribing Members on application to the Hon. Secretary, and will be entitled to receive the publications of the Society, but not to have a voice in the management of its affairs.

IV. The affairs of the Society shall be conducted by a Council consisting of a President, two or more Vice-Presidents, not more than twelve ordinary Members, Treasurer and Hon. Secretary, all of whom shall be Members of the Society.

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V. A General Meeting of the Society shall be held each year at which half the Council shall retire and at which the vacancies so created shall be filled for the ensuing year. All Members of Council shall be eligible for re-election, but the President shall not be eligible to hold office for more than two consecutive years.

VI. Nominations for Membership of the Council must be in the hands of the Hon. Secretary at least ten days before the Meeting.

VII. At the Annual General Meeting, the Treasurer shall submit a statement showing the financial position of the Society.

VIII. The Council shall have power to fill up vacancies in their number during the year, and to appoint any Member of the Society to serve on any Committee or Sub-Committee of the Council. Every such Committee or Sub-Committee shall retire at the end of the year, but may be re-appointed by the new Council.

IX. Every paper intended to be read at a Meeting of the Society shall be submitted to the Council for approval. A paper already published or read elsewhere shall not be accepted.

X. A Volume of Transactions of the Society shall be printed and issued to Members each year. The decision as to whether papers shall be given *in extenso* or in abstract, and as to the remaining contents of the Volume, shall be at the discretion of the Council. The Hon. Secretary shall supply to authors, at cost price, such reprints of their papers in the Volume as they may intimate their wish to have.

XI. The Publications of the Society for each year shall be issued to each Member whose subscription has been paid for that year. The Publications shall be sold to the public at a price to be fixed by the Council.

XII. The Subscription to the Society shall be £1 per annum, payable in advance on the 1st of October, which shall be the beginning of the financial year.

XIII. No alteration shall be made in this Constitution and these Rules except at an Annual General Meeting or at a Special General Meeting called upon the request of at least five Members. One month's previous notice of the alteration proposed must be given in writing to the Hon. Secretary, and the alteration must be approved by at least three-fourths of the Members present at such Meeting.

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The Newcomen Society Revenue Account.

From June, 1920, to September 30th, 1921.

Expenditure.

	£	s.	d.
To Hire of Rooms and Expenses of Summer and Ordinary Meetings	14	16	6
To Printing and Stationery	10	0	3
To Typing and Mimeographing	14	13	9
To Postages, Telegrams, Parcels and Stamps	6	8	8½
To Cabs and Travelling Expenses	0	10	6
To Laurel Wreath for Newcomen Monument at Dartmouth	1	0	0
To Cash on Deposit	55	0	0
To Cash on Current Account	23	3	9
	£125	13	5½

Income.

	£	s.	d.
By Subscriptions for the Year	97	0	0
By Donations for the Year	2	13	8
By Members' and Visitors' Contributions to Summer Meeting	13	1	0
By Bank Interest	1	19	11
By Cash due to Treasurer	10	18	10½
	£125	13	5½

The above Accounts have been examined with the Books and Vouchers, and found correct.

(Signed) A. M. BUSHELL, Hon. Auditor.

(Signed) H. W. DICKINSON, Hon. Treasurer.

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The Newcomen Society

LIST OF MEMBERS.

CORRECTED TO MARCH 1st, 1922.

o indicates Office Bearer.

Addison, Herbert, B.Sc., A.M.Inst.C.E., 100, North Station Road, Colchester.

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Bailey, R. U., St. Vincents, Lichfield Road, Four Oaks, Nr. Birmingham.

Barraclough, Sir Henry E., K.B.E., B.E. (Syd.), M.M.E. (Cornell), M.Inst.C.E., M.I.Mech.E., University of Sydney, New South Wales.

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PLATE I.

RICHARD LENARD'S FIREBACK, 1636.

From original in the collections of the Sussex Archæological Society.
Actual size 20½ ins. wide by 21¾ ins. high.

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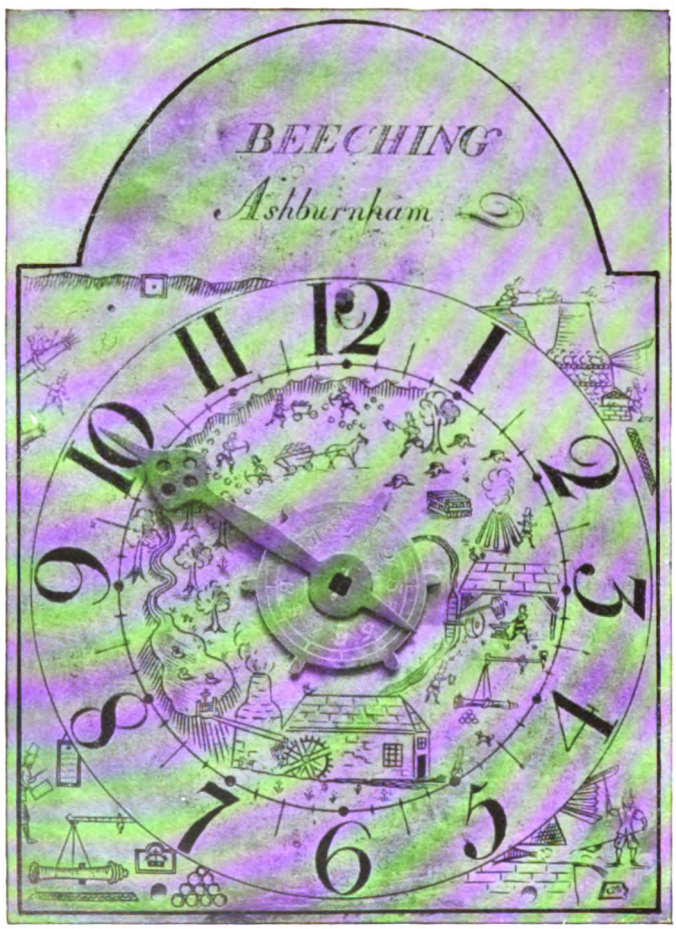
PLATE II.



BRASS DIAL OF THIRTY-HOUR CLOCK.
From Hayden's *Chats on Cottage and Farmhouse Furniture.*
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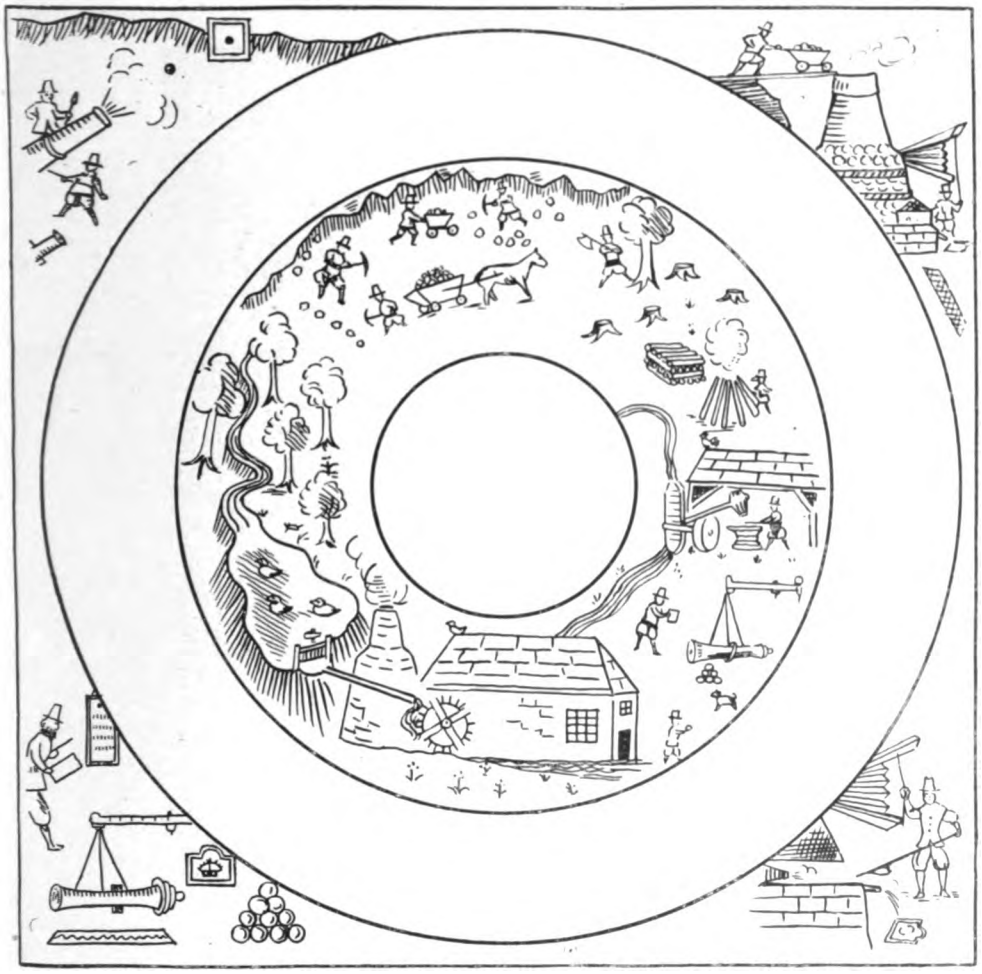

CLOCK FACE OF PLATE II., as drawn by MR. W. A. YOUNG.

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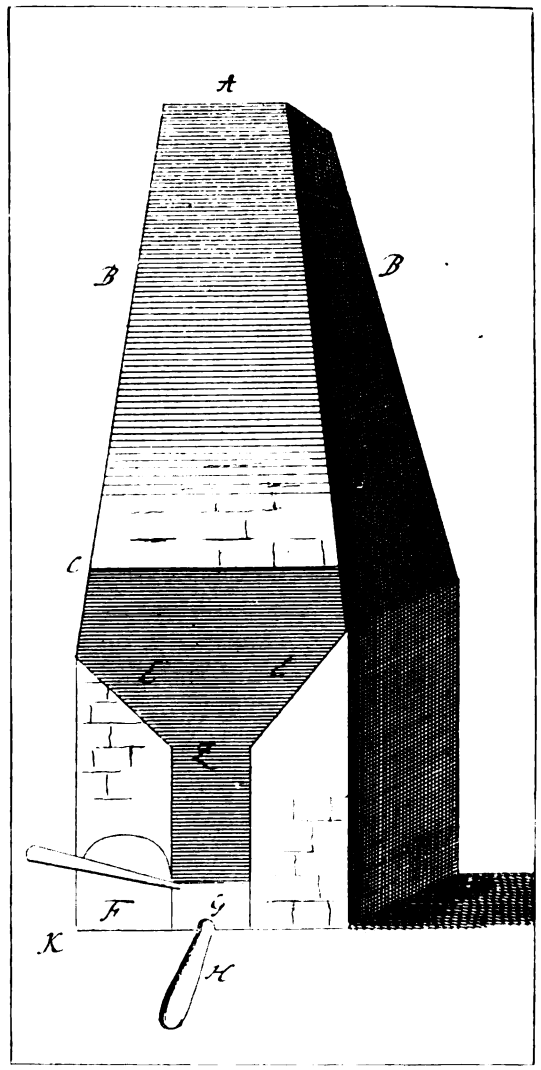

GLOUCESTER (LAMBERHURST) FURNACE.
(Swedenborg: De Ferro, 1724).

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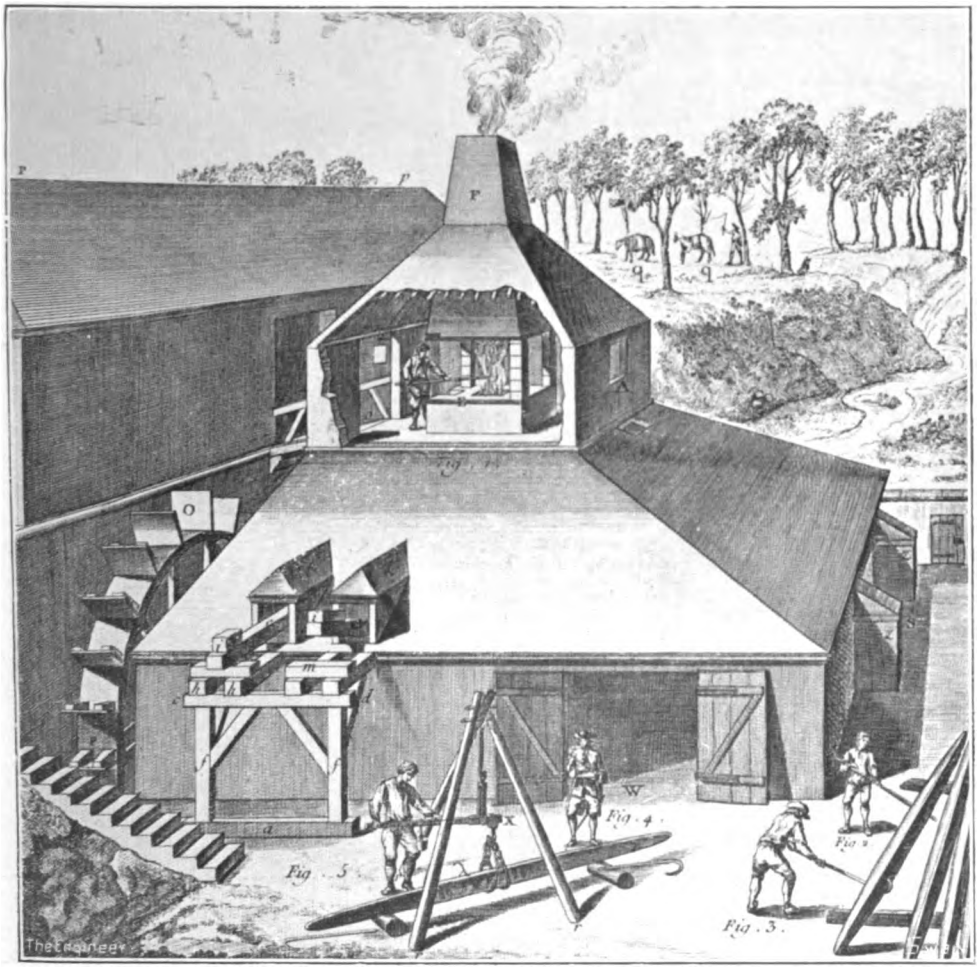

IRONMAKING IN FRANCE.—THE BLAST FURNACE.
(Encyclopédie: Diderot & D'Alembert, 1757-1765).

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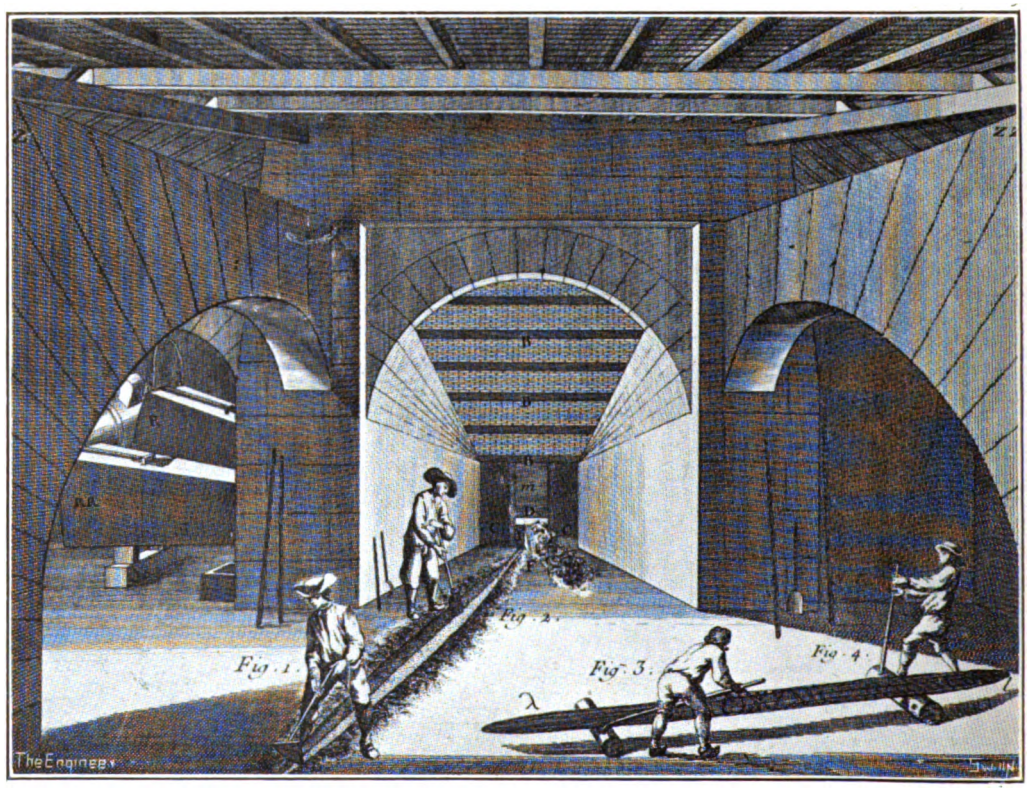

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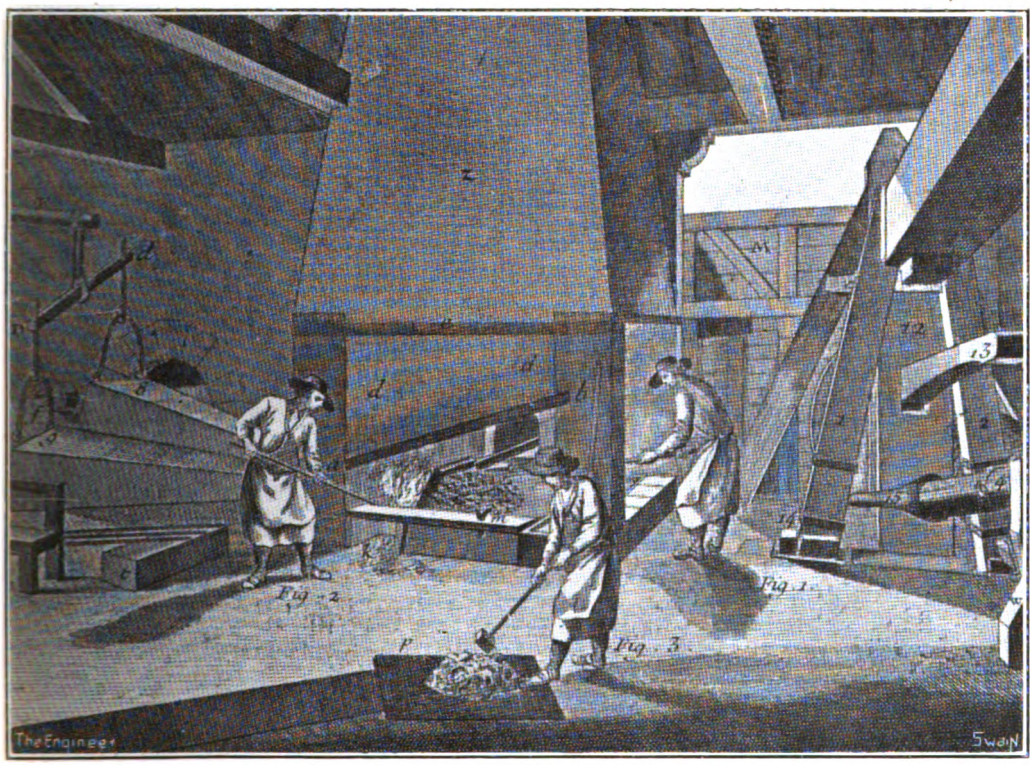

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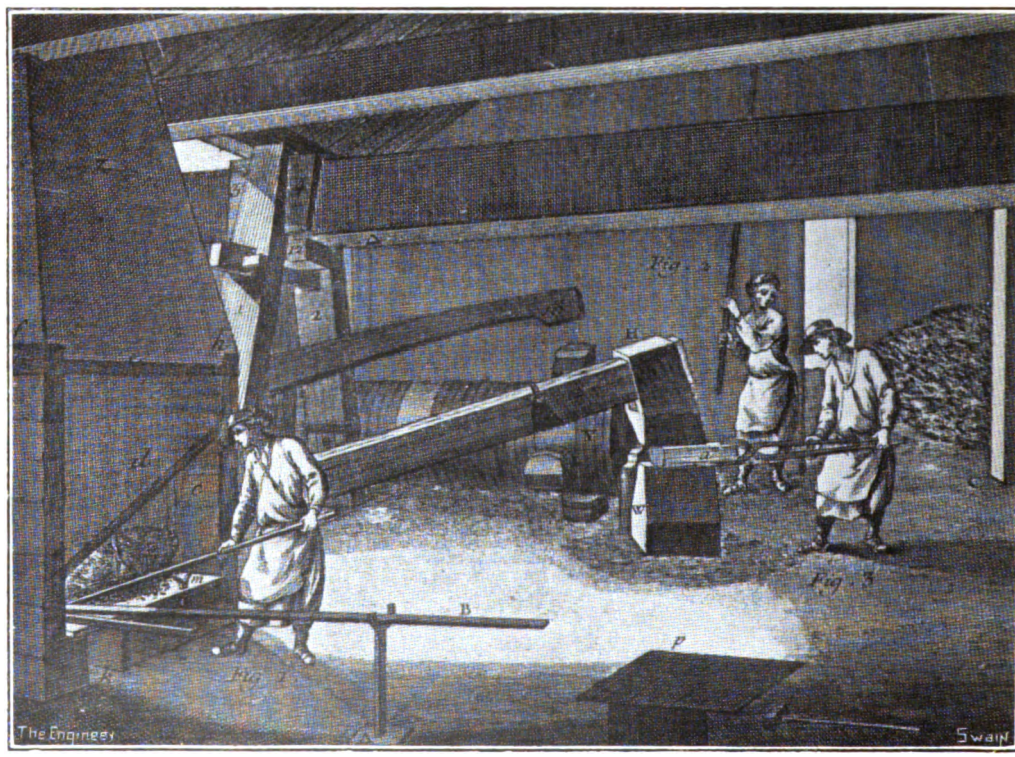

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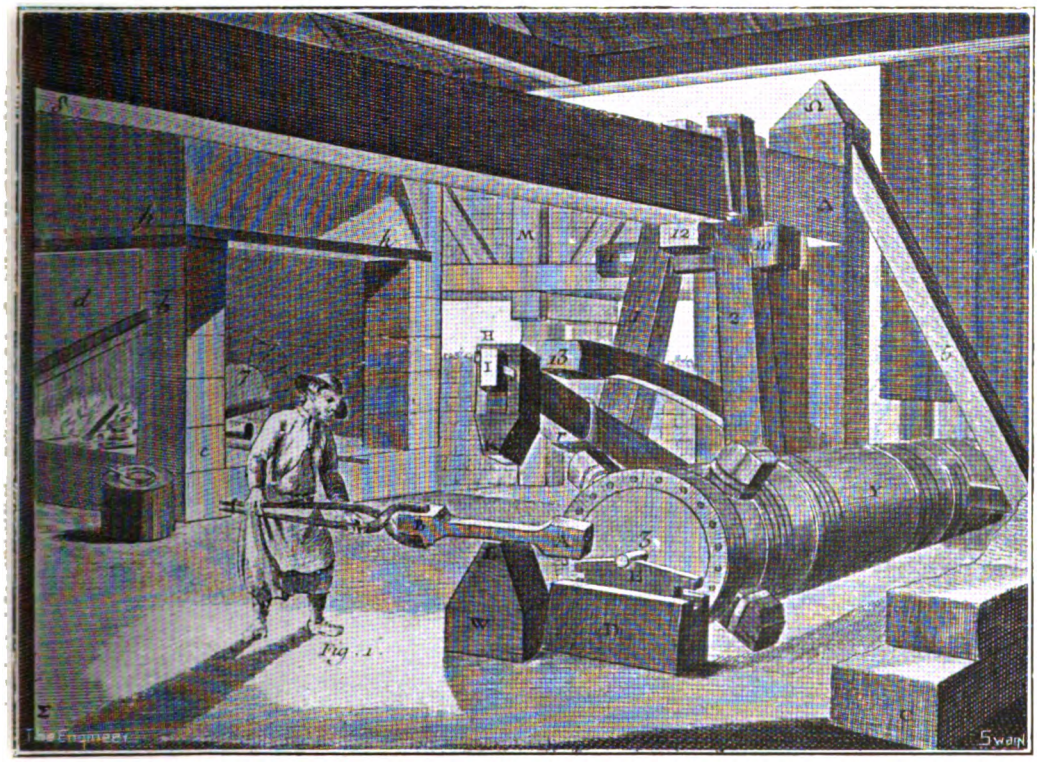

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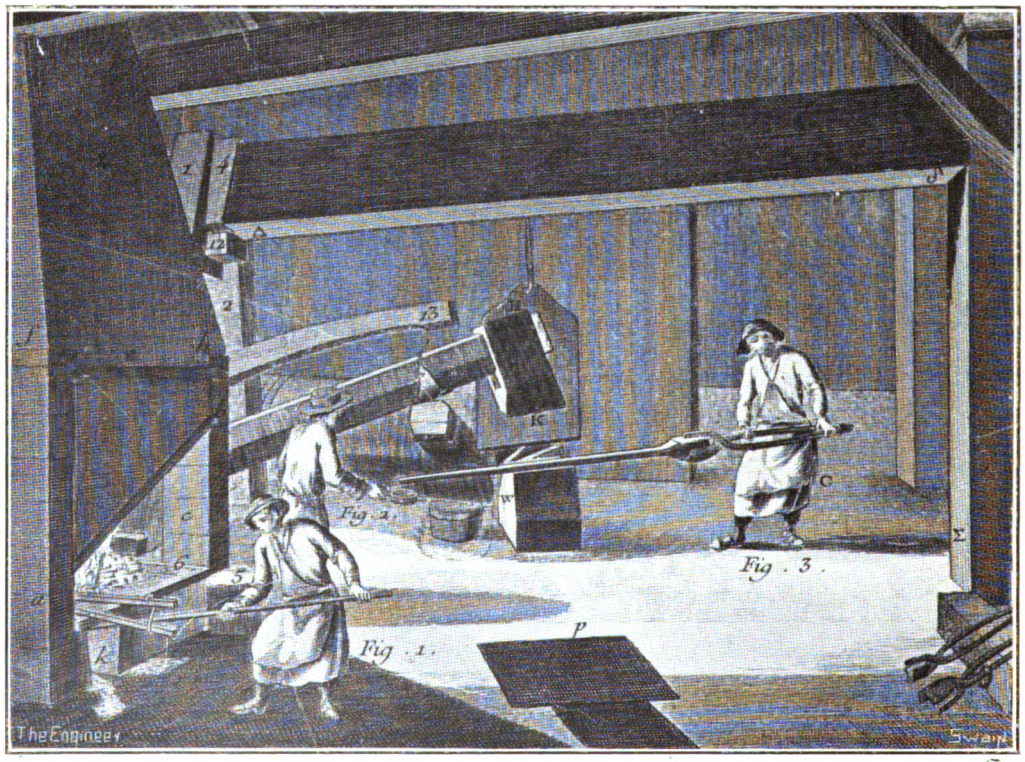

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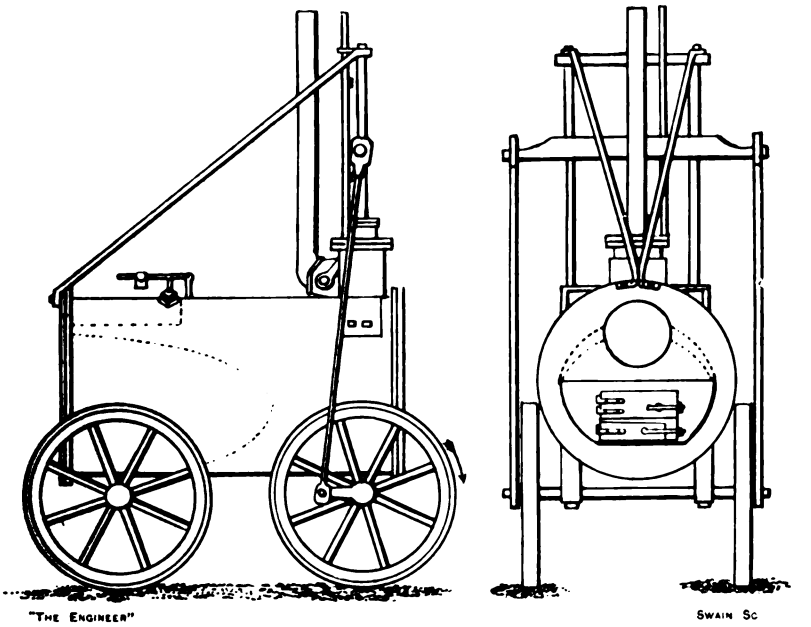

FIG. 1. TREVITHICK'S FIRST LOCOMOTIVE MODEL.

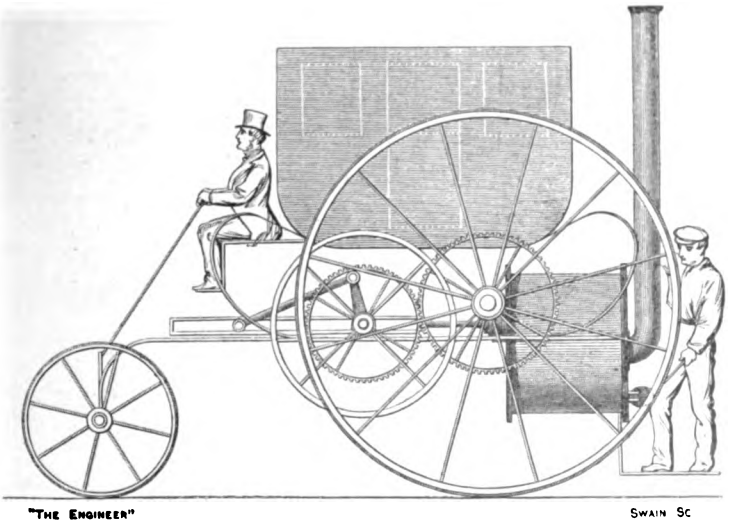

FIG. 2. TREVITHICK'S STEAM COACH OF 1803.

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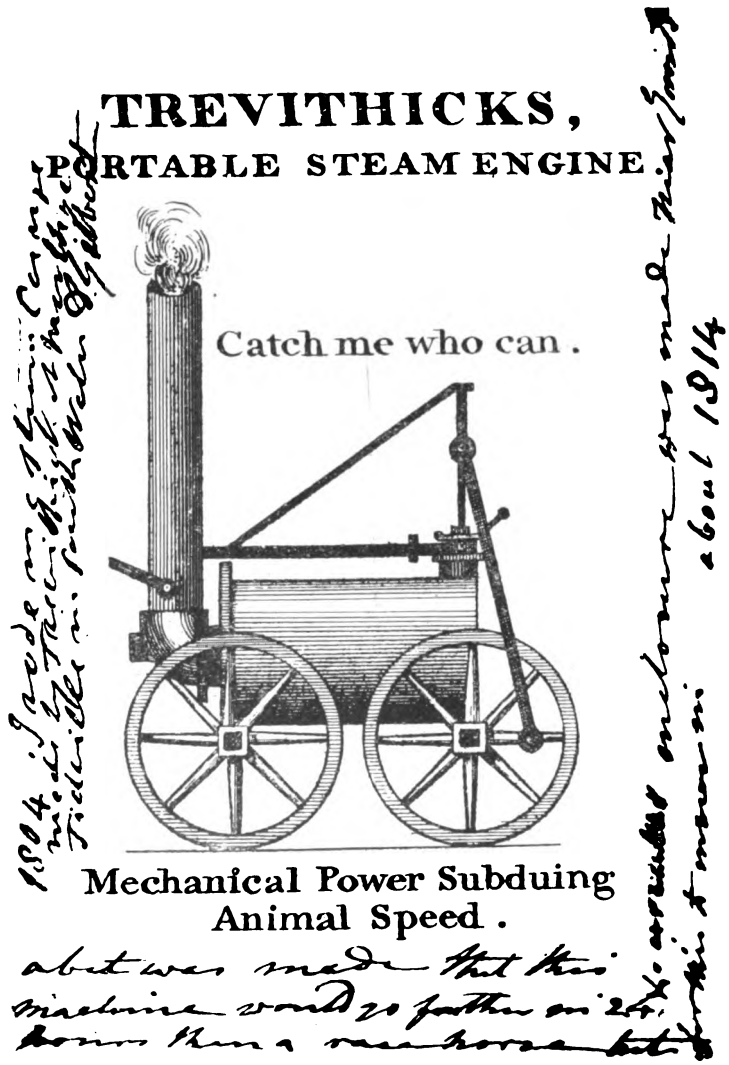

TREVITHICK'S BUSINESS CARD.

From Harper's *The Cornish Giant.*

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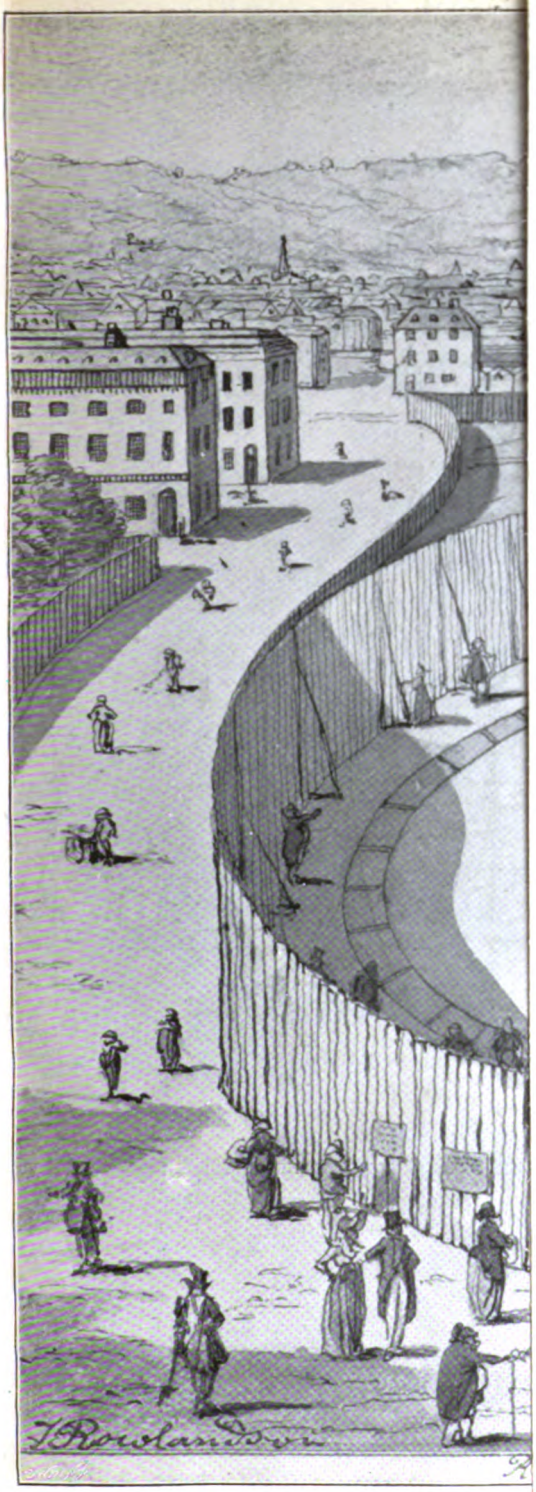

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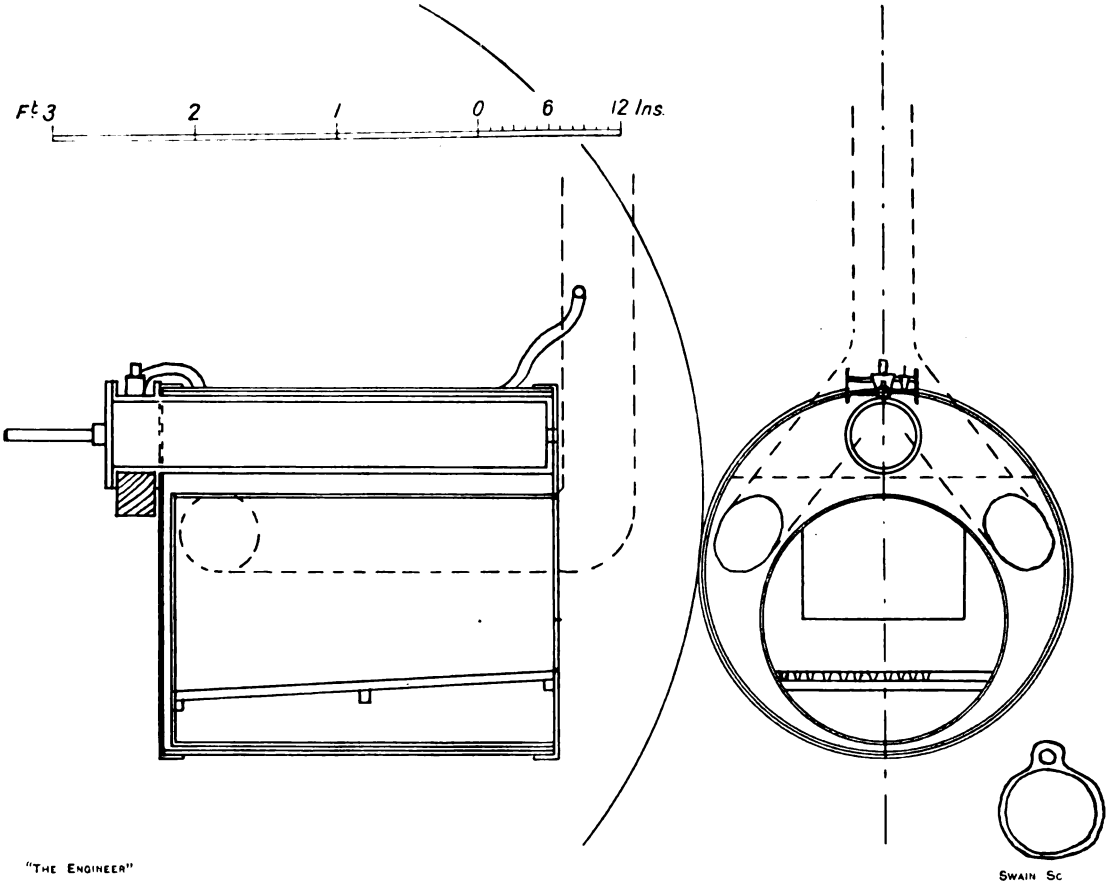

GOODRICH'S SKETCH OF TREVITHICK'S COACH ENGINE OF 1803.

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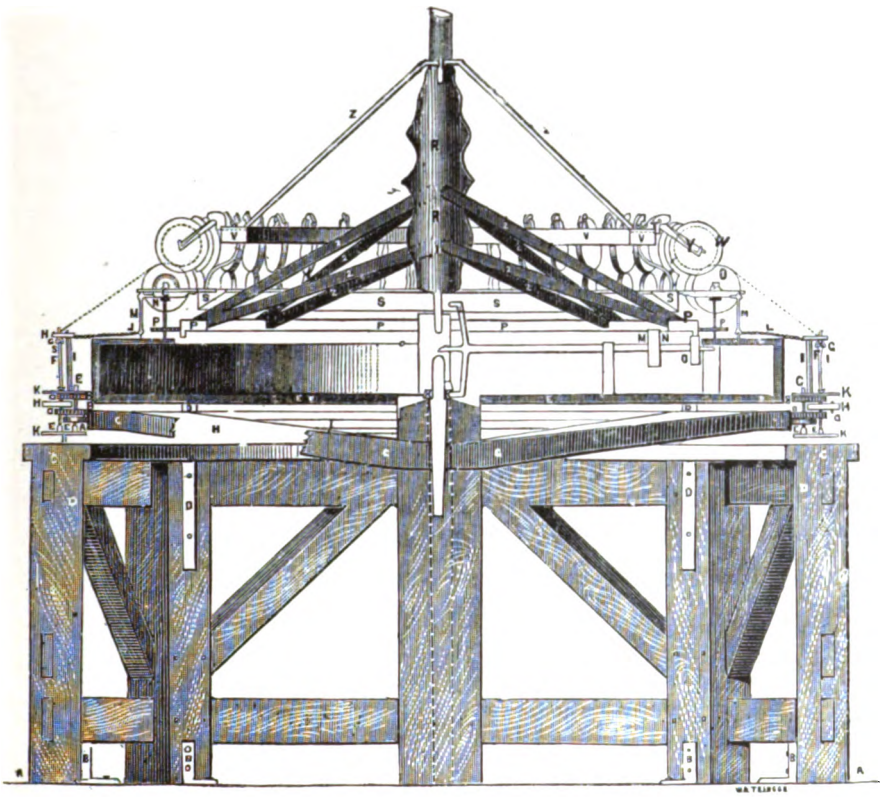

PAUL'S SECOND SPINNING MACHINE, 1758.

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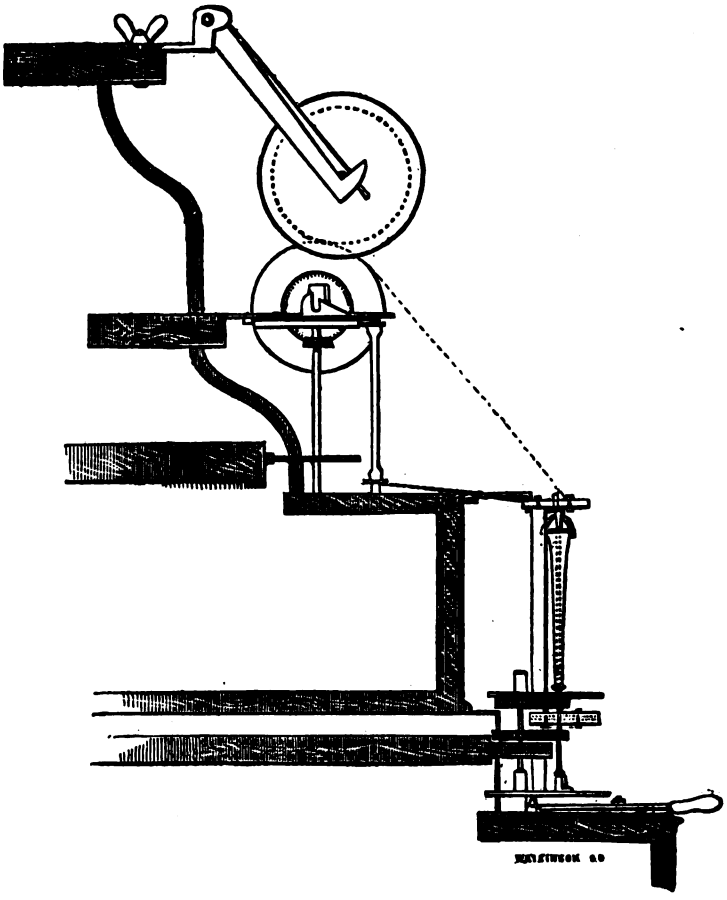
PLATE XVI.



ENLARGED SECTION OF PAUL'S SECOND SPINNING MACHINE.

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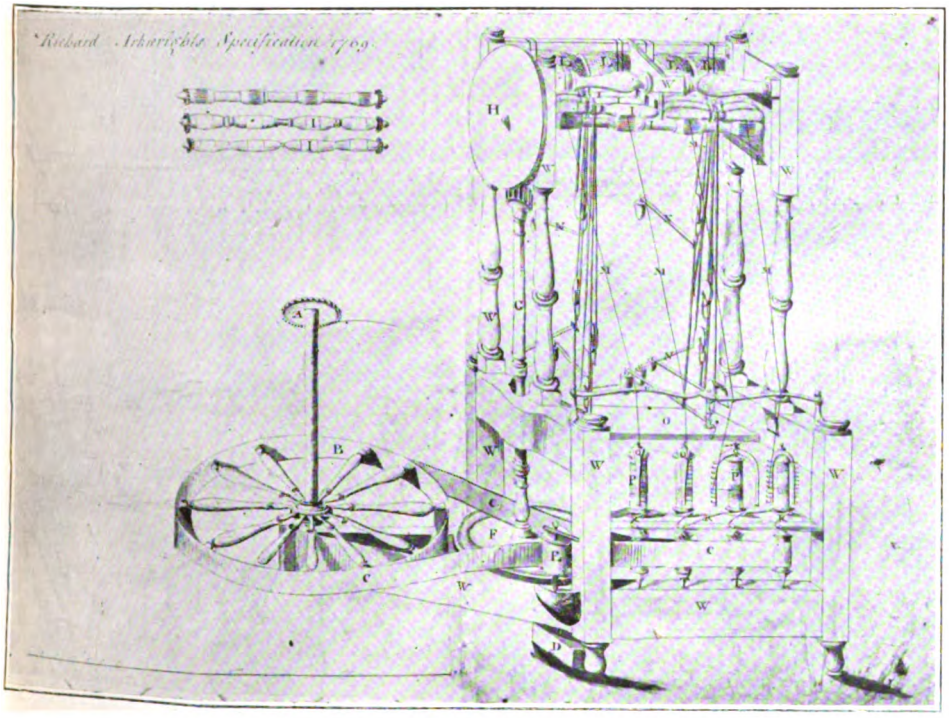
PLATE XVII.



ARKWRIGHT'S SPECIFICATION DRAWING OF HIS SPINNING MACHINE, 1769.

From the original in the Record Office.

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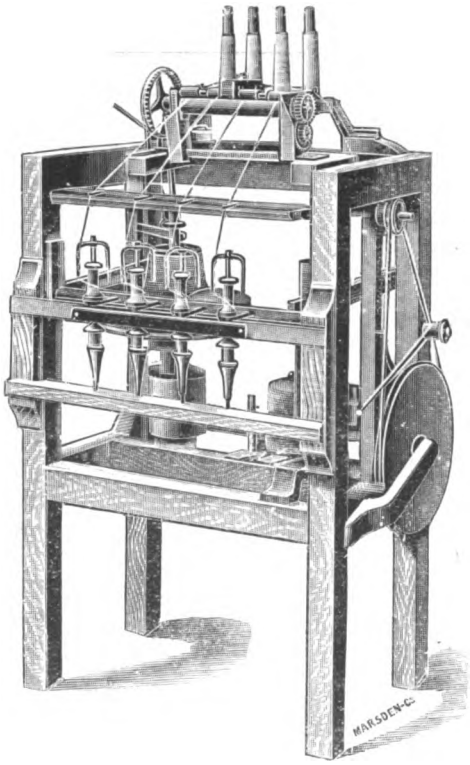

FIG. 1. ARKWRIGHT'S IMPROVED SPINNING MACHINE OR WATER FRAME, *c.* 1775.

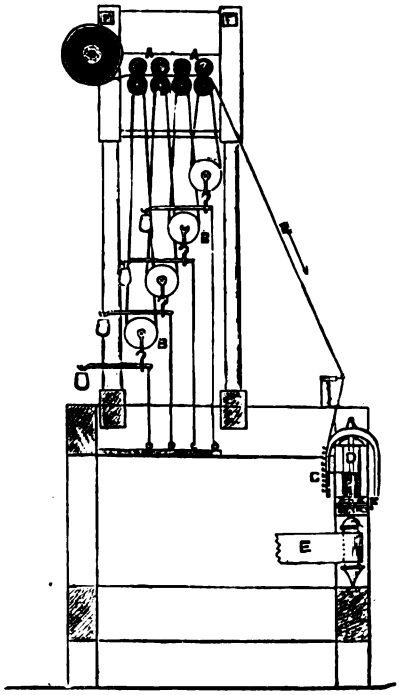

FIG. 2. SECTION SHOWING ARKWRIGHT'S DRAWING ROLLER SYSTEM.

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for the study of the history of

ENGINEERING and TECHNOLOGY

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EMBLEM OF THE SOCIETY.

On this volume appears the emblem that the Council has adopted after much deliberation. Devices, such as a Newcomen engine, that might seem to identify the Society with one particular aspect of its activities, were considered but rejected. Recourse was had to a heraldic device, and the griffin, emblematic of vigilance, was finally adopted. The beast is represented looking backward while yet going forward. The motto, due to Col. Kitson Clark, Member, expresses this idea; it may be freely rendered: "Mindful of what has been done, we strive at the same time after the things yet to be done."

CORRIGENDA IN TRANSACTIONS, VOL. I.

P. 10, l. 26, for "Hoover Brothers" read "Mr. and Mrs. Hoover."

P. 17, l. 29, for "Côté" read "Côte."

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"The Early History of Mechanical Handling Devices."

By G. F. Zimmer, Assoc.M.Inst.C.E.

(*Read at the Institute of Marine Engineers, October 12th,* 1921.)

The first machines ever built by man were more than probably labour-saving devices for the conveyance of water. Of these the "chain-of-pots" is the progenitor of the bucket elevator, while the "Chinese chain-pump" is that of the continuous conveyor. Another device is the Archimedean screw, also used in antiquity for conveying water, but it is of small importance as a modern conveyor.

Handling Water in a Vertical Direction by the "Chain-of-Pots."

In its earliest days the "chain-of-pots," which is supposed to have originated in Persia, consisted of an endless fibre rope, or pair of ropes, to which earthenware pots were attached at uniform intervals. The pots, on passing over the upper terminal wheel (which was about 6ft. in diameter) discharged into a trough; as a rule there was no lower terminal. Thomas Ewbank[1] states in 1842 that the device may safely be regarded as coeval with the foundation of the city of Babylon, if not, as was probably the case, of much more ancient date. The same device was probably the pump which, according to tradition, Danaus introduced into Greece (Pliny VII, 56) a thousand years before the taking of Babylon by the Persians. Though no details were given concerning the type of water-raising machine introduced by Danaus, the "chain-of-pots" may be inferred, from the punishment meted out to his daughters, who had to draw water from deep wells, for which purpose they would naturally use the machine introduced by their father.

The reference to leaking vessels is also applicable, since every pot had to have a small hole in its base through which the air could escape when filling in an inverted position. The poetical allusion—symbolising man's life—in the XIIth chapter of the Book of Ecclesiastes:—

> ". . . . Or ever the silver cord be loosed, or the golden bowl be broken at the fountain, or the wheel broken at the cistern,"

is undoubtedly a reference to the "chain-of-pots." The term "silver" refers

[1] "Hydraulic and Other Machines for Raising Water," 1842.

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to the bleached condition of the palm fibre ropes which were alternately wetted and exposed to the sun; " the golden bowl " is an allusion to the colour of the earthenware pots, both pots and cord dripping with water and glistening in the sun represented to the vivid imagination of the Oriental a striking resemblance to burnished gold and silver. And if the cord broke, which was not infrequently the case, the whole " chain-of-pots " would tumble into the well, breaking the pitchers and often the terminal driving wheel also, owing to its revolving either contrary to its wont, or at a speed for which it was not intended.

The machines by which the water was raised to the hanging Gardens of Semiramis were most probably also of this type, and if it is true that the city walls were over 300ft. high, it was a marvellous achievement for such an elevator, since our present-day practice rarely exceeds 150ft.

Perhaps the best-known example of an early bucket elevator or " chain-of-pots " is that at Joseph's Well, in Cairo. It was 165ft. in depth, and its capacity was between three and four gallons per minute. The " chain-of-pots " mentioned as being used in it consisted of two units, in series, and this was probably also the case at Babylon.

The " chain-of-pots," or " sakia," which is still in use in Egypt to this day, is illustrated in Plate I. It is mentioned by Sandys in 1611, and by Poncet in 1698.

Amongst the earliest references in literature to the " chain-of-pots," Paternoster, or Jacob's Ladder work, is that made by Philo of Byzantium,[2] 230 B.C.; he describes and illustrates such a machine, which was employed for raising water, and was driven by a totally enclosed treadmill for one man.

A Roman bucket elevator as described by Vitruvius in 1548 is shown in Pl. II. Three similar elevators are illustrated in Agricola, 1556, one of which is reproduced in Pl. II. A similar device is mentioned by Capitano Agostino Ramelli,[3] 1588, and illustrated in Pl. VI. It is of special interest owing to the advance made in constructional details. The whole machine, with the exception of the framing, is of iron, the large driving wheel G, is of cast-iron, and the pinion of cast and wrought. It is driven by a " walking man " gear and countershaft. The upper terminal of the elevator consists of two cast-iron discs E and F, which are connected together by six wrought iron bars forming a hexagonal terminal. The most remarkable feature about the installation, however, is that all the spindles are supported by rollers (see H and I).

In the *Theatrum Machinarum Novum* (Georg Andreas Böckler, 1673), a great number of primitive chain elevators for raising water are illustrated and described. They were evidently much used during that period.

[2] " Pneumatica," Second Appendix, Art. IV.
[3] " Le Diverse et Artificiose Machine."

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The "chain-of-pots" was used in this country, according to R. D'Acres, prior to 1660, and was known as "bucket-work," "bucket gin," and "Scotch gin."[4] It was more particularly used in Scotland and in the north of England. It consisted of a chain of buckets with two endless, long-linked iron chains; the buckets themselves were either wooden barrels, boxes nailed together, as in Pl. VI, or were made of stiff leather. No illustrations of these first machines are available, but a bucket elevator[5] which was used in Bruges in 1663, and which is illustrated in Pl. III, evidently bears a close resemblance to the early British devices with wooden barrels. Other Continental cities are said to have been supplied with water by similar devices prior to the 16th century, and it is believed that the "chain-of-pots" was used in Holland as far back as the 14th century.

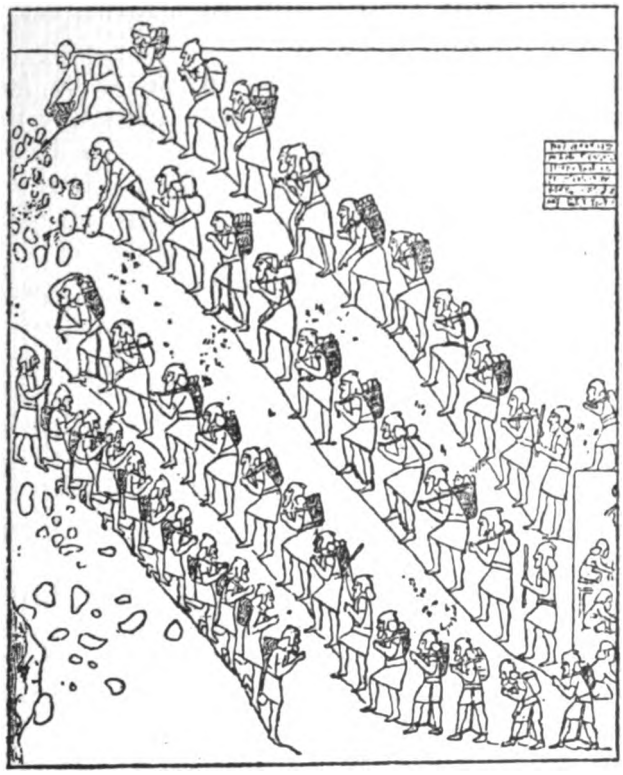

FIG. 1.—ANIMATED BUCKET ELEVATOR.

From an Alabaster Slab in the Palace of Sennacherib, c. 700 B.C., now in the British Museum.

[4] "The Art of Water-Drawing, A Compendious Abstract of all Sorts of Water Machines," 1660.

[5] This illustration is taken from "Mundus Subterraneus," Athanasius Kircher, 1665.

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HANDLING WATER ESSENTIALLY IN A HORIZONTAL DIRECTION, BY THE CHAIN PUMP.

The Chinese Chain Pump, see Pl. III,—known in the land of its origin as "*Fan Tschi*" and "*Chin Chia,*"—which may be fitly taken as the progenitor of most of the continuous working conveyors, and of the push-plate or scraper conveyor in particular, is also of great antiquity, and is closely connected with the agriculture of China; it has undergone no change whatsoever in China up to this very day. It is mentioned in Chinese literature* as early as A.D. 1145. It is described by Gamelli[6] in 1695 as a device which only Chinese ingenuity could have invented, while a fuller description and illustrations are given by Leupold,[7] 1724. Reference is also made to this machine by Sir George Staunton in an account of an Embassy from the King of Great Britain to the Emperor of China in 1796, from which the illustration, Pl. IV., is taken, while the following description is from Leupold and Staunton:

This device consists of a wooden trough divided in the inside along the middle, by a board, into two compartments. Flat and square pieces of wood, corresponding exactly to the dimensions of the trough, are fixed to an endless chain, which travels over a roller or small wheel placed at each extremity of the trough; the square pieces of wood fixed to the chain move with it round the rollers and push forward a volume of water equal to the dimensions of the trough. The most common practice of driving this device is by a simple crank turned like a grindstone on one of the terminals, the machine being of wood, including the chain, only the square spindle with its crank is of iron. The terminal to which the crank is fitted is a cylindrical piece of wood with a square hole in its centre for the spindle; in its circumference there are six longitudinal grooves, into which fit six small boards, forming a hexagonal spider, there is a small niche in the centre of each of these boards with which the chain engages, and the pitch of the chain is such as to fit from niche to niche, so that three links of the chain are always in mesh with the terminal.

It is believed that the Dutch introduced the chain pump into Holland, since in 1624 they established a colony on the south-west coast of Formosa, at a time when no other foreigners were permitted to enter China. The Dutch settlers must have been acquainted with this device, and it was also introduced by them into Batavia in the 17th century, while the Spaniards introduced it into Manila and their own country about the same time. Further, the device was introduced into France by wandering Jesuits, and was there used for raising water up an incline from the river Seine, for the inhabitants of Paris.

*"K'ien-Ling Keng Tschi t'u," 1145 A.D.; the literal translation of which is "*Pictures of Ploughing and Weaving.*"

[6] "Histoire Générale," Tom. VII., 267.

[7] "Theatrum Machinarum," 1724.

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George Sinclair,[8] 1672, describes the method of removing water from coal mines, and it appears from his description that the Chinese chain pump, as well as the "chain-of-pots" was used in Scotland in his day.

In the 18th century the Chinese chain pump was introduced into England.[9] During the building of Blackfriars Bridge the water was raised from the caissons by this device, about 1750.

The first recorded European use of this Chinese invention refers to Holland, where it was apparently largely used for removing silt from harbours and docks; it is referred to by Cornelius Meyer,[10] a Dutch engineer, in 1685. The illustration accompanying the description is insignificant, but so far as it goes it resembles closely the machine described by Johann van Zyl,[11] 1734, illustrated in Pl. V, which shows that considerable improvements have been made on the primitive Chinese original. According to Leupold, a similar machine was installed in Amsterdam in 1708, under the name of "Modder Moole," or, in English, mud machine. Leonhardt Christoph Sturm,[12] 1721, recommends the use of the Dutch "Modder Moole" to remove silt from waterways. It was stated by Ernst Christian August Behrens, 1789, that Sturm had introduced some improvements in the design of these Modder Mooles. In 1785, Grundy,[13] engineer of the Hull Docks, had a machine built after the Dutch original for clearing the mud from the dock; all these machines were driven by horse gins. As the Chinese chain pump is not mentioned by D'Acres, it was probably not known in this country prior to 1680.

The same device, says Leupold, was employed in Berlin and the neighbourhood to replace the Archimedean screw formerly employed for raising water.

According to the book published anonymously in 1860, by the artist Colesworthy Grant,[14] chain pumps were used in Mulnath, Bengal, in the manufacture of indigo (see pl. iv.). The same type of chain pump was also used by Chinese workmen at the Larut Tin Mines,[15] about 1897.

The Development of the Bucket Elevator from the "Chain-of-Pots."

The next development, which replaced the manual operation shown in Fig. 1, concerned the raising of solids such as sand, gravel and probably mortar, to the

[8] "Hydrostatics," Edinburgh, 1672, pp. 298, etc.

[9] "Hydraulic and Other Machines for Raising Water," Thomas Ewbank, 1842—footnote on page 149.

[10] "L'Arte di restituire a Roma la tralasciata Navigatione del suo Tevere," Roma, 1685.

[11] "Theatrum Machinarum Universale," 1734; also described by L. van Natrus, 1734-36.

[12] "Vollstandige Anleitung Schiff-Haüser oder Arsenale und Anfahrten oder See-Häfen gehörig anzugeben," 1721.

[13] "Mechanics' Magazine," Vol. 39, p. 309.

[14] "Rural Life in Bengal," 1860.

[15] "Professional Papers on Indian Engineering," Second Series, Vol. VIII., No. 31, January, 1879, by Pat. Doyle, C.E., Superintendent of Public Works, Straits Settlements.

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top of city walls for building or repair work. Such a machine is given by Besson,[16] 1578, shown in pl. viii. This gives some details of construction: In the upper portion of the picture, on the left, the top terminal is shown, driven by worm and worm gearing, while on the right the lower terminal is illustrated; it is provided with tommy bars for a man to assist in turning the machine. A feature of importance in the working of elevators is the application of the rollers shown in this detail for the support of the loaded run. A similar device for the same purpose is shown in pl. ii., taken from Ramelli, 1588. These elevators are evidently very slow working, as one man fills the buckets with a spade in the moat of a fort, while another on the rampart turns the crank; in the foreground may be seen the details V and M of the upper terminal.

The gravity bucket conveyor is shown in its incipient stage in Fig. 2; it is described and illustrated by Dr. Robert Hooke,[17] as in use in 1692. What is a

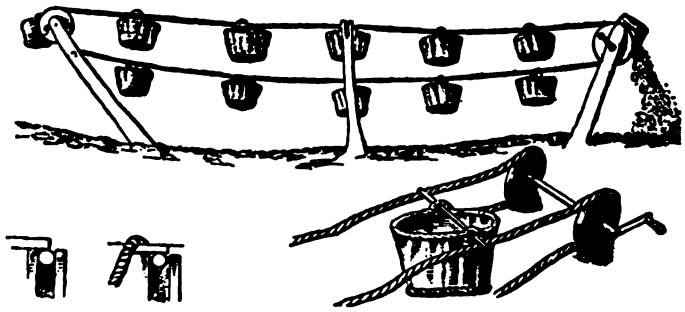

Fig. 2.—Primitive Gravity Bucket Conveyor.
From the "Philosophical Experiments" of Dr. Hooke, 1726.

further development (see pl. viii.) is the invention of Thomas Arkwright,[18] Kendal, Westmoreland, and is intended for raising ore, etc., from mines. The inventor was awarded a bounty of twenty-five guineas by the Society of Arts.

The Introduction of Elevators and Conveyors in Flour Mills.

We next find that the principle of primitive water-handling devices was applied to elevators and conveyors, in the first industry which man ever pursued to any great extent, *i.e.*, the manufacture of flour and the handling of grain at a time after it had ceased to be a domestic drudgery and had become an established industry.

[16] "Theatre des Instrumens," Jacques Besson, 1578.
[17] "Philosophical Experiments and Observations of the Late Eminent Dr. Robert Hooke," London, 1726.
[18] "Repertory of Arts, Manufactures and Agriculture," 1802, Vol. I., Second Series, p. 26.

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The American millwright, Oliver Evans (1755-1819), by his inventive genius and practical ability, was the first to improve materially the millstone process of milling, of the last century. His chief inventions or introductions were the bucket elevator; the Archimedean spiral conveyor; a primitive form of push-plate conveyor which he named " drill "; also a simple form of band conveyer, termed by him " the descender." By the employment of these devices the necessary operations through which the various materials had to pass in the mill, were performed mechanically, from the time the grain was received from the wagoner's bag or from a vessel, until the flour and offal were taken off into sacks. Several drawings of ideal mills on Evans' system are shown in his book *The Young Millwright*, which was first issued in 1795. The invention of elevators, conveyors, etc., was claimed by Oliver Evans, but was disputed and a lawsuit was commenced in Baltimore County Court, which was decided in Evans's favour, although it afterwards appeared that he was not the original inventor, for a plate from an old magazine was produced, showing sections of a mill in Germany in which elevators and conveyors were in operation at a date many years before that of their introduction into America. An exhaustive search through the German milling literature, available at the Patent Office Library, reveals the following: Lukas Vohs,[19] in his book published in 1780, makes no reference to labour-aiding machines for handling grain or meal, whilst the Treatise of Ernst Christian August Behrens,[20] published in 1789, and that of Joseph Krakovitzer,[21] 1790, likewise contains no reference whatever to elevators and conveyors, either in the letterpress or in the numerous plates in the former work. Dr. Carl Hartmann, in his Treatise on Anglo-American Mills, 1857, gives a minute description of elevators and worm conveyors, which were practically unknown in Germany, even at that time, for in the preface he admits that German mills have made practically no progress, being still at the same stage as they were a hundred years previously, whereas England, France and America reformed their systems and equipments during the last twenty years of the 18th century. It would be most interesting to trace the book from which the plate referred to above was taken.

William Fairbairn[22] was the first in this country to describe intelligently elevators and worm conveyors in his Treatise, published in 1863. We may take it from this that labour-saving devices of the millwright's type made their appearance generally in British flour mills somewhere about 1850, although they were in use, sporadically, as early as 1816.

[19] " Milling and Mill Gearing," Augsburg, 1780.
[20] " The Art of Milling," Schwerin, 1789.
[21] " Getraide-Muhlen," 1790.
[22] " Mills and Millwork," 1863.

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Introduction of Handling-Machinery in Gas Works, Power Houses, &c.

A perusal of the *Journal of Gas Lighting*, from the date of its first appearance in 1849, should furnish a reliable record of the progress made in this direction. During the first thirty-one years of its existence (1849 to 1880), however, no mention of elevators or conveyors is to be found in the index of this journal. There is unmistakeable evidence that the then existing methods of manual handling were not all that might be desired, for Mr. V. Wyatt, constructing engineer of the Gaslight and Coke Company, February 15th, 1881, contributed an article to that journal on the subject, which forms a fitting prologue to the introduction of labour-saving devices. He asserted that the handling problem in gas works was as essential to modern practice as the manufacture of gas itself. He illustrated his article by citing the progress made at the gas works at York, Newcastle-on-Tyne, and Beckton. He only solved part of the problem, however, by advocating, in addition to a more advantageous layout of the works, a system of sidings and inclines by means of which a train of coal wagons could be taken into the retort-house—conveyors and elevators at that time were apparently not yet considered an essential part of a gas plant. The first article to appear in the *Journal of Gas Lighting* actually advocating the use of mechanical conveyors in gas works, was published in the issue of March 18th, 1890. It was written by Norton H. Humphreys, M.Inst.C.E. He, as Wyatt had also done, harped on the labour troubles, and said that the greater part of the wages, as set forth on the weekly labour wages-sheet, were for the simple conveyance of material; coal wheeled into the retort-house, coke wheeled out; coal put into the retorts, and coke extracted therefrom, etc., etc.

We may, therefore, date the advent of handling devices in gas works—including also the first hot coke conveyors, from about 1890, *i.e.*, about 40 years later than their introduction into the milling industry.

Collieries and power stations began to instal such machines at about the same time.

Conveyors as Feeding Devices to Other Machines.

We have already seen that practically all types of the conveyors we use to-day were well known in a more or less primitive form eighty or more years before the industries generally were ready for them, as practically no conveyors were employed as independent handling units between 1800 and 1870, except those primitive devices in flour mills, already mentioned. They were, in fact, in advance of their time. Such devices were, however, employed for feeding and delivery purposes, forming integral parts of many machines that came into use at that period. The use of these diminutive conveyors and elevators might be

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said to constitute a transition period before their installation as separate units of more extensive dimensions. Such devices were introduced about the period 1790 to 1870 and some are still used in the same way to-day. The purpose for which such small conveyors, rarely longer than 3 ft., were introduced, was to keep the labourers out of harm's way and protect them from injury which might be caused by their carelessness and clumsiness, they being in ignorance of the dangers of fast-running machinery. On the other hand, such feeding devices promoted a more uniform rate of supply of the raw materials, which is unquestionably also essential.

Mechanical Handling of Material in Situations which are Inaccessible to Workmen.

There was also another early application of most types of elevators and conveyors before their employment for their legitimate purpose, for we find that during the period 1800-1870 material handling devices were installed for the purpose of dealing with objects or materials in situations which were inaccessible to workmen. For instance, conveying material slowly through heated retorts, chambers, ovens or furnaces, as in gas and other chemical works; for biscuit and bread baking; as Lehr conveyors in glass factories; chain-grate stokers, etc.; also for raising soil from submerged areas.

The Affinity of some Primitive Motors with Modern Conveyors.

Contributory evidence to prove that the principle upon which some of our modern conveyors are constructed was known and well understood at an earlier date may be gathered from the fact that motors actuated by animals or human beings, apart from gins and other well known devices, in at least two cases were on the same underlying principle as conveyors, or might have been conveyors had they been driven instead of being made to drive.

The object in mentioning these devices is to show that the technical knowledge needful for building conveyors was not lacking, and that the reason why they were not built and used one hundred years earlier was simply that men were contented to work for a lower wage and that the masters could see no advantage in buying or building conveyors. We may thus attribute the delay in the installation of conveyors in industrial establishments of all kinds to the abundance of manual labour available at that time and to the fact that the quantities to be handled, *i.e.*, tons per annum, were, generally speaking, too small to justify their introduction.

The Latest Developments Fostered by Sheer Necessity.

When making an historical survey of the more modern appliances in use for handling raw materials and merchandise by mechanical means, it must be realized

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that handling engineering owes its existence not only to industrial development, by which the quantities to be handled have increased by leaps and bounds, from insignificant figures to huge totals, but also in a large measure to the gradually increasing cost of manual labour. It is impossible to employ hand-labour to-day unaided by mechanical appliances, without burdening the cost of production to an extent which must seriously hamper progress. The increased cost of hand labour and its hostile attitude gradually forced the introduction of mechanical elevators and conveyors in gas works.

One of the devices fostered by necessity was the "Hunt" automatic railway, invented by C. W. Hunt, in consequence of the strikes of coal wharf operatives in New York in 1871.

The well-known "Dodge" system of accumulating large piles of anthracite coal was introduced in America in 1885, owing to a strike of the coal haulers at the docks of the Philadelphia and Reading Railway Company at Philadelphia.

Another such example was the introduction of the pneumatic system by Duckham in 1891; he was compelled, on account of strikes at the Millwall Docks in 1887—which paralysed the unloading of grain vessels—to find other means to safeguard the food supplies.

Labour cost and labour troubles are thus directly connected with and responsible for the advent of modern labour-aiding machinery. It is obvious that since the labour question has become chronic and acute within the last three or four decades, the latest development is a comparatively modern subject, although some of the progenitors of handling devices date back to a very early period.

Few circumstances in the history of invention are more striking to those who philosophize upon its progress than the fact that many of those inventions which have ultimately produced the most marked and decisive results in the march of human progress, have been made, tried, laid aside, and for a time left in oblivion, and then resurrected from the limbo to which they had been consigned.

The author illustrated his paper by twenty-three lantern slides; from the originals of some of these, Figs. 1 and 2 in the text, and Plates I. to VIII., have been prepared.

Discussion.

At the conclusion of the paper, a vote of thanks was moved by Mr. Pendred, who pointed out the distinction between anti-friction and roller bearings; it was seconded by Mr. D. E. Roberts, who, in a recent visit to the Far East, had seen apparatus described by the author in daily use. The vote of thanks was carried unanimously. In the discussion, the president referred to the pioneer work in

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corn milling of Oliver Evans in America and of William Fairbairn in England, whose arrangements for handling materials had persisted to the present day.

Mr. Rhys Jenkins said he had failed to find out when the first ordinary band conveyor was introduced.

Sir George Greenhill was struck by the impression of great mechanical efficiency and small power required, as represented in the illustrations. He thought the work of Archimedes should be mentioned, c. 250 B.C., in hauling a laden ship over dry land.

The Secretary said the paper showed that a number of handling devices were invented long ago; it was the coming of the self-contained motor to replace hand power that rendered them applicable generally.

Col. F. W. Foster mentioned the engine for raising water alluded to by Stow in the 16th century.

The Author, in reply, bore out the remarks of the President as to the work of early corn-milling engineers. The first band conveyor he had come across was that of Oliver Evans, who called it a "descender"; with subsequent improvements by Westmacott, it was in use at the present day.

*The blocks for Figs. 1 and 2 and for Plates III. and VIII. have been kindly lent by the Editor of the "Electrician"; the rest have been lent by the Author.

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The Liverpool and Manchester Railway.

By C. F. Dendy Marshall, M.A., M.I.Loco.E.

(*Read at Caxton Hall, Westminster, November 16th, 1921.*)

SECTION I.—GENERAL HISTORY.

In the first quarter of the nineteenth century, owing to the importation of cotton from America, and its manufacture in Lancashire, the need for increased facilities of inland communication in that part of the country became very urgent. Between the years 1780 and 1824 the population of Liverpool increased from 26,000 to 125,000, and that of Manchester in the same period from 22,000 to 160,000. Goods were conveyed between them by road, and by two canals, the Irwell and Mersey Navigation, and the Bridgewater. The disadvantage of these canals was that they were liable to obstruction by drought in summer and ice in winter, and ended at Runcorn, about sixteen miles from Liverpool, the remaining passage of the Mersey estuary being difficult and dangerous in bad weather. In addition to these natural inconveniences, the canal companies profiteered scandalously, and there appears to have been no end of pilfering, while the delays were interminable.

In 1797 William Jessop had suggested that a tramroad to be worked by horses should be laid down between these two towns, and surveyed a route. The following year Benjamin Outram made another survey for a line, but nothing came of either proposal. Thomas Gray, in his "Observations on a General Iron Railway," first published in 1820, advocated commencing with one between Liverpool and Manchester, but the credit for the earliest practical scheme is due to William James. Born in 1771, he took up the business of land agency, later becoming the proprietor of a number of collieries, and the manager of others. As early as the beginning of the following century he had projected many railways, some of which were constructed, chiefly in connection with the mines in which he was interested, and the estates which were under his supervision. About the year 1808 he put forward a proposal for a "general railroad company," with a capital of a million pounds, also one for a tunnel under the Thames. He had the foresight to advocate the use of locomotives, and to realise the possibilities of profit arising from passenger traffic, in both of which ideas he was well in advance of the times.

In 1821 he drew up a plan, based on a preliminary survey, for a "Line of Engine Railroad from Liverpool to Manchester," in which he succeeded in interesting Joseph Sandars, a Liverpool merchant, who became one of the most active

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promoters of the line, and subsequently (1824) published a pamphlet in its favour. The first survey, in which Charles B. Vignoles took part, was very imperfect, and a second was made in 1822, with the assistance of Robert Stephenson. Soon afterwards, owing to ill-health and financial embarrassments, James became incapable of proceeding further with the matter, and the committee which had been established to carry out the project appointed George Stephenson as engineer. A company was formed, and in October, 1824, the first prospectus was issued.

An improved survey was carried out, in the teeth of great opposition from the landowners, and early in 1825 an Act of Parliament was applied for, the application being unsuccessful. However, the promoters determined to try again the following session, after introducing certain modifications which avoided some of the worst of the difficulties they had experienced.

In the place of George Stephenson they appointed George and John Rennie as engineers, who had an established reputation, and employed Charles Vignoles to prepare the fresh plans. The new line avoided the properties of its most powerful opponents as far as possible, and entered Liverpool by means of a tunnel and steep gradient, so as to obviate the necessity for crossing streets, which had been strongly objected to. The Marquis of Stafford was diplomatically approached, and induced to become a large shareholder, which caused the opposition of the Bridgewater trustees to be withdrawn. The result was that the Act was obtained in April, 1826. Construction was immediately commenced, and proceeded with during the next four years and a half, all difficulties being eventually overcome by the resourcefulness and determination with which they were assailed.

The appointment of a chief engineer was taken into consideration immediately after the passing of the Act. The directors proposed to give the post to George Stephenson, under the superintendence of the Rennies. The latter, however, preferred to appoint their own resident engineer, suggesting that Stephenson should be placed in charge of the locomotive department, to be distinct from the other works. The Board then made up their minds to place Stephenson in sole charge, dispensing altogether with the Rennies. His assistants were Joseph Locke, William Allcard, and John Dixon, also, for a few months, Vignoles.

While the work was going on, much discussion took place on the subject of motive power. After a visit to the Northumberland and Durham Railways in 1826, the directors came to the conclusion that horses were out of the question, which was therefore narrowed down to locomotives *versus* stationary engines.

Early in 1829, being still unable to agree on this very vital subject, the Board decided to seek outside professional advice, and applied to Mr. Walker of Limehouse, and Mr. Rastrick of Stourbridge, for a report as to the respective merits of locomotive and fixed engines. Both were engineers of standing, Walker after-

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wards becoming the engineer for the Blackfriars bridge, while Rastrick had built the "Stourbridge Lion," which was the first engine to run on rails in America.

In March, after visiting and observing the methods of working on the Bolton, Middleton, Stockton and Darlington, Hetton, Killingworth, and Brunton and Shields railways, they issued a report. It contains a mass of detail which is of little interest at the present time, and, although on the whole recommending the employment of stationary engines, cannot be said to be very decided on the point. In fact, Lardner says that it was in favour of locomotives. They estimated the capital cost as less for locomotives, and the annual expense as in favour of fixed engines, but did not omit to point out that the locomotive system could be easily expanded to meet increased requirements in the future, and that there was more ground for expecting improvements in their case. These two considerations alone seem almost of sufficient weight to turn the scale, but even yet the directors did not feel able to come to a decision.

With a view of giving the locomotive one more chance, so to speak, they resolved to invite a competition with a prize of £500, the conditions being advertised in April, 1829, and the trial taking place in October. The construction of the "Rocket" was at once begun, being the nineteenth locomotive built by the firm of R. Stephenson and Co.

The story of the contest has been told over and over again. The success of the "Rocket"—setting aside the fact that she did not break down, which her rivals did—was due to the combination of the tubular boiler, and a suitably proportioned blast pipe (or perhaps pair of blast nozzles), which supplemented one another, as the tubes would have had little effect without a strong draught, and a powerful blast in the old type of boiler would have pulled the fire through and sent it up the chimney. The tubes were adopted at the suggestion of Henry Booth, the treasurer of the company, and the arrangement worked out so happily by the Stephensons is in universal use at the present day.

There was no longer any doubt as to the desirability of having locomotives, and several were ordered immediately, eight being ready for the opening ceremony, which took place the 15th September, 1830. The proceedings, together with the unhappy accident to Mr. Huskisson, have been frequently described, the greatest detail being given in a pamphlet published by J. F. Cannell. It is rather fortunate than no further accident occurred, as the victim was conveyed to Eccles by the "Northumbrian" at the rate of 36 miles an hour, and the Duke of Wellington's carriage, being left without an engine, was towed the rest of the way to Manchester by a train running on the other line! This carriage, which conveyed the principal guests, ran on eight wheels, and was a wonderful affair, 32 feet long,

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with a canopy supported on gilt pillars, more like a triumphal car in a circus than a railway vehicle. On the return journey most of the passengers were made to walk up the "inclined plane" at Sutton.

The length of the line was 31 miles. It was double throughout, 18 miles being at first laid on stone blocks, and 18 on oak or larch sleepers, these being employed on the embankments.

The cost was about £800,000, of which the principal amounts in round figures were: Bridges, £100,000; cuttings and embankments, £200,000; land, £100,000; parliamentary and law expenses, £28,000.

The line commenced at Wapping close to the docks, thence through a tunnel 1,980 yards long up a gradient of 1 in 48, where stationary engines were used to pull the trains up to Edgehill. After a short level piece, there was a down grade of 1 in 1,092 for five miles, passing through the Olive Mount cutting, along the Broad Green embankment, to the Whiston plane, which was 1½ miles of 1 in 96 up. It was intended to use fixed engines for this gradient, and at the corresponding one called Sutton, and according to the description published by Cannell, they were actually erected, but this is doubtful, and the climbs were usually surmounted by means of piloting. The line then passed along the Rainhill level, where the competition had been held, under the celebrated skew bridge, which is still in its original state, and down the Sutton incline, also of 1 in 96. Crossing Parr Moss on a solid embankment, slightly falling, it went over the Sankey Valley on a viaduct of nine arches, then descending 6¾ miles of 1 in 880, it passed over Chat Moss on a "floating" embankment 4¾ miles long rising 1 in 1,200, the run into Manchester being a level 4¾ miles, finally crossing a street called Water Street by an iron bridge which is still just as it was when built.

The greatest difficulties, in fact the only really serious ones, were encountered in the formation of the section over Chat Moss, which was one of the last remnants of a line of fen, uncultivated mosses and morasses, stretching across England as late as the 16th century, from the mouth of the Ouse at Lynn to the Mersey. How these difficulties were overcome is set forth in considerable detail by Smiles.

The arrangements at Liverpool, which were designed so as to disarm opposition by keeping the railway as little in evidence as possible, were inadequate and inconvenient, and within a few years of the opening a new large station was built at Lime Street, where the station is at the present day, connecting with Edgehill by means of a fresh tunnel, a new station being also made at Edgehill, a little farther away. The tunnel has since been almost entirely opened up, and the line now runs in a cutting.

A contemporary account of the carriages says: "The most costly and elegant contain three apartments, and resemble the body of a coach (in the middle) and

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two chaises, one at each end—the whole joined together. Another resembles an oblong square of church pews, panelled at each end, and the rail which supports the back so contrived that it may be turned over, so that the passengers may face either way."

There were three classes, the first and second being closed carriages with separate numbered seats, but differing in the space allowed to each passenger. The third were completely open at first, but were furnished with roofs by 1833, the sides being still left unprotected. Some writers call the three classes mails, first and second. The trains were also divided into first and second class; the latter of which appear to have been those which included open carriages, and altogether there is some little ambiguity as to the exact use of the names.

The fares given in "Bradshaw" for 1840 and 1842 are as follows: "First class train, 4 inside, royal mail, 6/6; ditto, 6 inside, glass coach, 6/-. Second class train, glass coaches, 6/-; ditto, open carriages, 4/6."

Signalling was at first done entirely by hand. A description in 1833 says: "The Company keep a police establishment who have station houses at intervals of about a mile along the road. These stations also form depôts for passengers and goods from or to any of the intervening places. . . . When a train approaches within a certain distance of a station, the policeman presents himself, and signifies a clear road by assuming an erect posture with his arm outstretched: should he take the position of 'stand at ease,' the engineer is aware that some obstruction exists. When a passenger is waiting at the station a red flag is hoisted by day, and a swinging lamp exhibited at night."

About 1838 pivoted boards were introduced for use in the daytime, being turned across or parallel to the track, according to whether the line was blocked or clear. It appears to have been assumed to be the latter about four minutes after the passage of a train.

A tremendous revolution in social habits was brought about by this railway. The promoters had in view principally the carriage of goods, not anticipating that passenger traffic would be of much importance. Yet in the year 1831 the receipts from passengers amounted to nearly half a million pounds, the goods traffic being carried on "with the few engines that can be spared," as one account states. The rapid development that took place is well exemplified in a comparison of the primitive arrangements shown in the illustrations of 1831 and the view of Lime Street Station published in 1836.

The subsequent history of the line can be summed up in a few words by saying that it joined with the Grand Junction in 1845, and in 1846 the combined system was amalgamated with the London and Birmingham under the name of London and North Western Railway.

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SECTION II.—THE LOCOMOTIVES.

1.—Engines used during the construction of the line.

One was the "Lancashire Witch." She had four wheels coupled together, with cylinders at the back, steeply inclined downwards, working the leading pair of wheels direct. The boiler had two flues, each containing a fire, the total weight being about twelve tons. Forced draught was supplied by a fan on the tender. She was afterwards employed on the Bolton and Leigh Railway.

Another was a curious engine, specially constructed for steep gradients, with two boilers and chimneys, named the "Twin Sisters." She ran on six-coupled wheels with inclined direct acting cylinders. Subsequently to the completion of the line she was used by the contractors who supplied coke to the railway.

Several other early engines, including the "Rocket" and "Novelty," were also used.

2.—Competitors at Rainhill.

(a) "Rocket." Built in 1829 by R. Stephenson and Co. Four wheels, the drivers, which were 4 feet 8½ inches in diameter, leading. The cylinders, 8 by 17, were at the rear end, inclined forwards and downwards at an angle of 37 degrees. Steam pressure, 50 lb. per square inch; 25 3-inch tubes; heating surface 117.75 sq. feet; fire box, 20; total, 137.75 sq. feet. Weight in working order: engine, 4 ton 5 cwt.; tender, 3 ton 4 cwt.; total, 7 ton 9 cwt.

On the day of the trial she was painted yellow and black, with the chimney white. She is said to have been fitted with a smokebox and shorter chimney before the opening. Subsequently the cylinders were lowered to an angle of 8 degrees, being changed over, so as to bring the valves above instead of below. She worked on the L. and M. Ry. till 1836, and was then transferred to the Midgeholme line, near Carlisle, ceasing work in 1844, being brought to South Kensington in 1862.

(b) "Novelty," by Braithwaite and Ericsson. This engine, which was built in six or seven weeks, Vignoles helping to provide the money, had four equal wheels, of the suspension type, at first coupled with a chain, which was removed almost at once, being considered unnecessary. The cylinders were vertical, working upwards, and actuated the rear pair of wheels by means of bell cranks. She was painted dark blue, and embellished with burnished copper. The weight was only 2 tons 15 cwt. It is probable that she afterwards worked on the St. Helens and Runcorn Gap Railway, of which Vignoles was the engineer, which became part of the North Union.

(c) "Sanspareil," by Timothy Hackworth. Four wheels coupled, the cylinders working vertically downwards on the rear pair. Weight 4 tons 15 cwt. 2 qrs. After the trial she was purchased by the directors for £500, and sold in

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1832 to the Bolton and Leigh Railway for £110, where she worked until 1844, and was then employed at a colliery as a pumping and winding engine until 1863. Now in South Kensington Museum.

(d) "Perseverance," by Burstall of Leith. Details of this engine, which was a failure, are almost entirely lacking from the accounts of the competition. Hebert states that the arrangement was similar to that of a steam road coach, built by the same engineer in 1824. The coach had vertical cylinders, acting upwards, and driving the wheels through grasshopper beams. An old print of the Rainhill competition shows a sketchy representation of the "Perseverance," which agrees with the above account, resembling "Puffing Billy" in general arrangement. She was fitted with a feedwater heater.

3.—Locomotives used for working the railway.

A.—List of engines down to 1840.

No.	Name	Date	Makers	Driving Wheels Ft.	Driving Wheels In.	Cylinders	Design
1	Rocket	1829	R. Stephenson & Co.	4	8½	8 x 17	'Rocket'
2	Meteor	1830	"	5	0	10 x 16	'Northumbrian'
3	Comet	"	"	"		"	"
4	Arrow	"	"	"		"	"
5	Dart	"	"	"		"	"
6	Phœnix	"	"	"		"	"
7	North Star	"	"	"		"	"
8	Northumbrian	"	"	"		"	"
9	Planet	"	"	"		"	'Planet'
10	Majestic	"	"	"		"	'Northumbrian'
11	Mercury	"	"	"		"	'Planet'
12	Mars	"	"	"		"	"
13	Samson	1831	"	4	6	14 x 16	4 wheels coupled
14	Jupiter	"	"	5	0	11 x 16	'Planet'
15	Goliath	"	"	4	6	14 x 16	'Samson'
16	Saturn	"	"	5	0	11 x 16	'Planet'
17	Sun	"	"	"		"	"
18	Venus	"	"	"		"	"
19	Vulcan	"	Fenton, Murray & Co.	"		"	"
20	Etna	"	R. Stephenson & Co.	"		"	"
21	Fury	"	Fenton, Murray & Co.	"		"	"
22	Victory	"	R. Stephenson & Co.	"		"	"
23	Atlas	1832	"	"		12 x 16	'Samson'
24	Vesta	"	R. Stephenson & Co.	5	0	11 x 16	'Planet'

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No.	Name	Date	Makers	Driving Wheels Ft. In.	Cylinders	Design
25	Milo	1832	R. Stephenson & Co.	5 0	12 x 16	'Samson'
26	Liver	,,	E. Bury & Co.	,,	11 x 16	'Planet'
27	Pluto	,,	R. Stephenson & Co.	,,	12 x 16	,,
28	Caledonian	,,	Galloway & Co.	,,	,,	4 wheels coupled
29	Ajax	,,	R. Stephenson & Co.	,,	11 x 18	'Planet'
30	Leeds	,,	Fenton, Murray & Co.	,,	11 x 16	,,
31	Firefly	1833	R. Stephenson & Co.	,,	11 x 18	,,
32	Experiment	,,	Sharp, Roberts & Co.	,,	11 x 10	Vertical cylinders
33	Patentee	1834	R. Stephenson & Co.	,,	12 x 16	6 wheels; single drivers
34	Titan	,,	Tayleur & Co.	,,	11 x 20	6 wheels; four coupled
35	Orion	,,	,,	,,	,,	,,
36	Swiftsure	,,	Forrester & Co.	,,	11 x 18	4 wheels; outside cylinders
37	Rapid	1836	Tayleur & Co.	,,	11 x 16	6 wheels; single
38	Speedwell	,,	,,	,,	12½ x 16	,, ,,
39	Hercules	1836	Mather, Dixon & Co.	,,	15 x 16	4 wheels; coupled
40	Eclipse	,,	Tayleur & Co.	,,	12 x 18	6 wheels; single
41	Star	,,	,,	,,	14 x 12	4 wheels ,,
42	York	,,	,,	,,	12 x 18	6 wheels ,,
43	Vesuvius	,,	Haigh Foundry	,,	12½ x 16	,, ,,
44	Thunderer	,,	Mather, Dixon & Co.	,,	13 x 16	,, ,,
45	Lightning	,,	Haigh Foundry	,,	12½ x 16	,, ,,
46	Cyclops	,,	,,	,,	,,	,, ,,
47	Milo	,,	Tayleur & Co.	,,	14 x 12	,, ,,
48	Phœnix	,,	,,	,,	,,	,, ,,
49	Dart	1837	Mather, Dixon & Co.	,,	,,	,, ,,
50	Majestic	,,	Tayleur & Co.	,,	,,	,, ,,
51	Etna	,,	,,	,,	,,	,, ,,
52	Arrow	,,	Mather, Dixon & Co.	,,	,,	,, ,,
53	Sun	,,	R. & W. Hawthorn	,,	,	,, ,,
54	Meteor	,,	Mather, Dixon & Co.	,,	,,	, ,,
55	Comet	,,	,,	,,	,,	,,
56	Vesta	,,	R. & W. Hawthorn	,,	,,	,, ,,

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No.	Name	Date	Makers	Driving Wheels Ft.	Driving Wheels In.	Cylinders	Design
57	Lion	1838	Todd & Co.	5	0	11 x 20	6 wheels; four coupled
58	Tiger	,,	,,	,,		,,	,, ,,
59	Rokeby	,,	Rothwell & Co.	,,		11 x 18	6 wheels; single
60	Roderic	,,	,,	,,		,,	,, ,,
61	Mammoth	1839	T. Banks & Co.	,,		12 x 18	6 wheels; four coupled
62	Leopard	,,	Todd & Co.	,,		11½ x 18	6 wheels, single
63	Mastodon	,,	T. Banks & Co.	,,		12 x 18	,,
64	Panther	,,	Todd & Co.	,,		11½ x 18	,,
65	Elephant	,,	,,	,,		14 x 20	6 wheels; four coupled
66	Samson	,,	Benjamin Hick	,,		11 x 20	,,
67	Buffalo	,,	Todd & Co.	,,		14 x 20	,,
68	Goliath	,,	Benjamin Hick	,,		11 x 20	,,
69	Victoria	,,	Mather, Dixon & Co.	4	6	12½ x 18	,,

B.—List of engines in use during 1844.

Coaching engines.				Luggage engines.				Jobbing engines.		
	Heron	(130)		30	Owl	(134)	1842	23	Atlas	(140)
	Kingfisher	(131)		31	Bat	(135)	,,	65	Mastodon	(119)
	Pelican	(132)		32	Raven	(144)		59	Rokeby	(–)
	Ostrich	(133)	1842	33	Crow	(145)		62	Leopard	(–)
	Stork	(136)	,,	65	Elephant	(113)			Ludwing	(–)
	Crane	(137)	,,	67	Buffalo	(121)		41	Star	(165)
	Pheasant	(141)		57	Lion	(116)				
	Partridge	(–)		58	Tiger	(117)				
60	Roderic	(118)		68	Goliath	(122)				
27	Pluto	(–)		38	Bittern	(142)				
	Swallow	(128)		39	Lapwing	(143)				
	Martin	(129)		40	Petrel	(149)				
	Swan	(138)	1842	41	Penguin	(148)				
	Cygnet	(139)	,,							
	Redwing	(146)								
55	Comet	(166)								
54	Meteor	(115)								
43	Vesuvius	(–)								
45	Lightning	(114)								
52	Arrow	(–)								

The numbers in brackets are those which the engines bore when taken over by the L. & N.W.R. Two not included in the above list which they also acquired were 53 Sun (164), and 69 Victoria (123). The North Western numbers of engines officially stated to have come from the L. & M. Ry. were 113 to 166, except 124 and 127, which were Bolton and Leigh engines.

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C.—List of engines subsequent to 1844.

Woodlark	...	Passenger	...	1845	...	(147)
Linnet	...	,,		,,		(150)
Goldfinch	...	,,		,,		(151)
Bullfinch	...	,,		,,		(152)
Chaffinch	...	,,	June	,,		(153)

(The following ten engines were of the 2.4.0. outside cylinder Allan type. Parts of each were made at Crewe, and parts by Rothwell & Co. Probably they had been ordered for the L. & M. line, but never received L. & M. numbers.)

154	Starling	July, 1845
155	Ousel	,,
156	Redstart	Jan., 1846
157	Redbreast	Feb., 1846
158	Condor	March, ,,
159	Adjutant	,, ,,
160	Flamingo	April ,,
161	Cuckoo	May ,,
162	Albatross	,, ,,
163	Osprey	July ,,

Another engine, details and date unknown, was said to have been the Soho, being the first locomotive built by Peel, Williams & Peel, of Soho Works, Ancoats.

The first eight engines took part in the opening procession on the 15th Sept., 1830, the "Northumbrian" leading.

The fast running done by the "Rocket" at Rainhill brought out the unsteadiness produced by her steeply-inclined cylinders, and in the rest of the class they were placed nearly horizontal. It is possible that she underwent this alteration during the period of nearly a year between the competition and the opening.

The detached firebox was retained down to the "North Star," No. 7, also the truck and barrel tender, the "Northumbrian" being the first to have a firebox integral with the boiler barrel, a buffer beam in front, and a respectable-looking tender. It is quite likely she was also the first to have a smokebox. As originally made, this appears to have been square in cross section; it is drawn thus on a jug showing the opening procession. No other representations of the engine in this state are known which are in perspective, but the shadow indicated in sketches in the *Mechanics' Magazine* of 16th October, 1830, and in *The Engineer* for 7th November, 1884, corroborates the evidence of the jug, which by itself would perhaps hardly go for much. In Shaw's etching of 1831 the smokebox is normal. A contemporary handkerchief also exists showing the "Comet" with a square smokebox.

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The subsequent history of the engines, in cases where the company parted with them, is usually impossible to trace. As time went on there would be a brisk demand among contractors for light engines to use on construction work, and probably a number were sold for this purpose. In a list of 1836, Nos. 3, 7, 15, 17, 20 and 25 are marked "sold," 5, 6 and 16 "broken up," and 8 and 10 "done with." By 1840 all that remained of the first 32 engines were Nos. 9, 11, 19, 21, 22, 23, 27, 29, 30 and 31. It will be noticed that many of the old names were repeated as time went on. Though the "Sanspareil" was purchased, and retained for a couple of years, she does not figure in the lists as part of the regular stock.

The "Planet" was a great step in advance, the cylinders being inside under the smokebox, with the driving wheels in the rear. This engine has been illustrated in more than one book on the locomotive with the frame passing under the driving axle and over the leading, a libel that is based on an old official drawing which has unfortunately survived, and evidently represents a design either never put into execution or abandoned before completion. Some of the contemporary sketches of this engine show a splasher over the driving wheel, with the name on it in large letters, in a curve.

No. 11, "Mercury," received the addition of a pair of trailing wheels at the end of 1833; possibly others of the class were similarly treated. In 1831 a new design appeared with four coupled wheels, the cylinders being dropped so as to clear the leading axle, the first engine being named the "Samson," intended for goods traffic. The "Atlas" was fitted with an additional pair of wheels which could be lifted off the rails by a steam cylinder.

No. 26, "Liver," was the only one of Bury's make which was actually purchased. She had single driving wheels and outside frames. Previously two earlier ones, named "Dreadnought" and "Liverpool," had been tried upon the line, but were not taken over.

No. 28, "Caledonian," by Galloway and Co., had vertical cylinders working upwards, with return connecting rods actuating a dummy shaft centrally disposed between the two axles, to which it was coupled. This is the form, anticipating Crampton, in which it is shown in a contemporary lithograph, and is therefore more likely to be correct than the design given by Stretton, in which the cylinders are ahead of the smoke box.

No. 32, "Experiment," by Sharp, Roberts, also had vertical cylinders, but over the leading wheels, operating the rear ones by means of bell cranks. Though alterations were made, it proved a complete failure.

In the next engine, "Patentee," we have the prototype of a favourite form

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of express engine for half a century. It was produced by lengthening the "Planet" design, and adding a pair of trailing wheels, and was highly successful. The feature of the patent was the omission of flanges on the driving wheels.

Nos. 34 and 35 were goods engines resembling the "Samson," with the addition of a pair of small trailing wheels.

No. 36, "Swiftsure," by Forrester and Co., was originally a four-wheeled engine with outside frames and outside horizontal cylinders, being the first engine with cylinders in this position. Drawings have been frequently given of her with six wheels, which was not her original condition. Owing to the wide spacing of the cylinders, this engine, and three similar ones supplied to the Dublin and Kingstown Railway, were very unsteady in running, being known familiarly as "boxers." In 1836 and 1837 an extraordinary fashion for short stroke set in (only 12 inches), which was not continued.

The list of engines in use during 1844, which is taken from the *Engineer* for 6th February, 1885, and supplemented by details supplied by Mr. Ahrons, shows that the life of these early engines was a very short one, less than half of them being as much as five years old. The above information is all that the author has been able to obtain.

A list of the engines in use on the L. and M. Ry. during the first half of 1845, is given in the appendix to the report of the Gauge Commissioners, 1846, but does not add anything material, except that "Samson" (66) is included among the "jobbing engines."

4.—Engines tried on the railway but not taken over.

It is probable that the "Novelty" was used to some extent at first. After the competition her makers, Messrs. Braithwaite and Ericsson, contracted to supply two locomotives to take 40 tons to Manchester in two hours on half a pound of coke per ton mile, which was about half the amount required by the other engines, the price being £1,000 each. They were named "William IV." and "Queen Adelaide," the first being put on the line about a week after the opening, and were enlarged editions of the "Novelty," with tenders. They were unable to perform the appointed task, and withdrawn by the builders, the failure being attributed by Ericsson to the fact that the fan for urging the draught was put at the top of the boiler, instead of blowing into the ashpan, as was done in the "Novelty." Ackermann's print of the bridge carrying the St. Helens Railway over the L. and M.R. shows one of them working on the former line.

Another remarkable engine which ran on the line for a time in the early days was the "Liverpool," by Edward Bury. The first engine he built, the "Dreadnought," which was also tried on the railway, was a failure. He then produced the "Liverpool" on quite different lines, the design being so good that he was able

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to employ it without substantial modifications for about fifteen years. She was of the well-known "Bury" type, with coupled wheels, of no less than 6 feet diameter, and worked on the L. and M.R. for some time, at last being rejected and sent to the Bolton and Leigh Railway.

It is interesting to note that negotiations were entered into by the Board with Goldsworthy Gurney, with a view to his supplying a locomotive, but these came to nothing, as the parties were unable to agree on the subject of terms.

SECTION III.—BRANCH AND CONNECTING LINES.

1.—Bolton and Leigh Railway.

In 1825 an Act was obtained for constructing a railway from Bolton to Leigh, followed in 1829 by one authorising the extension of the line to Kenyon, where it connected with the Liverpool and Manchester. It was opened 1st August, 1828 (Kenyon extension, 13th June, 1831). The total distance was 9 miles 6 furlongs. In 1840 it was leased to Mr. Hargreaves, of Bolton, who found the rolling stock, except a few engines for ballasting which belonged to the Company.

In 1840, in which year it was taken over by the Grand Junction Railway, it possessed 14 engines, one of which was the "Sanspareil." Three, named the "Victoria," "Utilis," and "Castle," were built by Hargreaves, the "Utilis" having eight wheels.

2.—St. Helens and Runcorn Gap Railway.

The Act for this line, which crossed, and connected by means of spurs with, the L. and M.R., was obtained in 1850, Vignoles being the engineer. The crossing was effected by a handsome stone bridge (see Pl. IX), which has since been superseded by an iron girder structure. The line afterwards formed part of the North Union Railway.

Information about this railway is difficult to obtain, but it is almost certain that the "Novelty" and her successors, the "William IV" and the "Queen Adelaide," were employed here. Vignoles was closely associated with Braithwaite and Ericsson, the builders.

3.—Warrington and Newton Railway.

This was a short line opened in 1833, Robert Stephenson being the engineer. It possessed three locomotives, the "Vulcan," afterwards "Achilles," "Warrington," and "Newton," built by Tayleur & Co., of the "Planet" type. In 1824 an attempt was made to obtain an Act for a railway between Birmingham and Birkenhead, to be called the Birmingham and Liverpool Railway, the year before the L. & M. made their first application to Parliament. Owing to the frantic opposition of landowners and canal companies the bill was thrown out, a second

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one sharing the same fate in 1826, in which year the L. and M. Railway were successful. After another failure in 1830, the promoters in 1833 obtained an Act empowering them to construct a line from Birmingham to Warrington, and to take over the Warrington and Newton, thus connecting with the L. and M. about the middle of its length, the junction now being called Earlestown. It was then named the Grand Junction Railway, as it formed the connecting link between the L. and M. and the projected London and Birmingham line.

In 1840 the G.J.R. possessed 64 engines, all with six wheels.

In 1845 it amalgamated with the L. and M.R., and the following year became part of the L. and N.W.R.

4.—Wigan Branch Railway.

This line, the Act for which received the Royal Assent the 29th May, 1830, ran from Parkside on the L. and M. to Wigan, a distance of about 7 miles. On the 22nd April, 1831, an Act was obtained for a line from Preston to Wigan, and the two were afterwards united in 1834 under the name of North Union Railway, which in 1846 was leased to the L. and N.W.R. and Lancashire and Yorkshire jointly, being finally dissolved in 1888. Vignoles was the engineer.

In 1840 there were 13 engines of the " Bury " type, without names.

SECTION IV.—DESCRIPTION OF THE EARLY VIEWS OF THE LINE.

The interest aroused by the railway led to the publication of a considerable number of illustrations, the demand for which appears to have lasted for about three years. The most beautiful series was that published by Ackermann. They were hand-coloured aquatints, produced at the time when this process was beginning to be superseded by the very inferior one of lithography.

Early in 1831 a set of seven was issued, 10 by 8 inches in size. They were drawn by T.T. Bury, and engraved by H. Pyall. After a certain number had been printed off, the titles and publication lines were erased, and a Spanish edition was printed, with titles in that language, without publication lines. The English titles and publication lines were then replaced, naturally showing small differences.

In July, 1831, six more plates were issued in a separate section, with eight pages of descriptive text.

Towards the end of the year two oblong plates were brought out, measuring 26 by 8 inches, each containing a representation of two trains.

In 1832 the thirteen small ones were published together, and another was added to the series, measuring 17 by 10¾ inches. The small plates were retouched from time to time, alterations to the buildings, etc., being worked in. The later impressions, dated 1833, are very inferior. Two of the Pyall plates were replaced by new ones engraved by S. G. Hughes.

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The title page of the first issue in February, 1831, was as follows:

"Six coloured views on the Liverpool and Manchester Railway, with a plate of the coaches, machines, &c. From drawings made on the spot by Mr. T. T. Bury. Price twelve shillings. London: Published by R. Ackermann, 96, Strand, and sold by R. Ackermann, Jun., 191, Regent St.; Printsellers in ordinary to His Majesty. 1831."

The succeeding English issues had the title page altered by the elimination of the word "six," and the addition of "With descriptive particulars, serving as a guide to travellers on the railway."

The title page to the Spanish edition was as follows:—"Seis vistas illuminadas del Camino de Hierro de Liverpool a Manchester con otra lamina de Coches, Maquinas, &c., &c., &c.

Londres: Lo Publica R. Ackermann, 96, Strand. MDCCCXXXI."

The description and titles to the plates were all in Spanish.

After the English edition of 1833, there was an Italian one of the two oblong plates, with titles in that language.

Publication lines on the prints:

A. Published Feby. 1, 1831, by R. Ackermann, 96, Strand.

B. London: Published Feby., 1831, by R. Ackermann, 96, Strand.

C. London: Published by R. Ackermann, Novr., 1831.

D. London: Pubd. by R. Ackermann, 96, Strand, 1831.

E. London: Published by Ackermann and Co., Strand, 1832.

F. Published Jany., 1833 by Ackermann and Co., 96, Strand, London.

G. London: Published by Ackermann and Co., Strand, Jany., 1833.

H. London: Published Feby. 1, 1833, by Ackermann and Co., 96, Strand.

J. London: Published Feby., 1833, by Ackermann and Co., 96, Strand.

K. London: Published by Ackermann and Co., Strand, 1833.

L. London: Pubd. by Ackermann and Co., 96, Strand, 1833.

M. London: Pubd. by Ackermann and Co., Strand, 1833.

N. London: Published 1834, by Ackermann and Co., 96, Strand.

O. London: Published 1832 by R. Ackermann, No. 96, Strand, and J. and J. Mawdsley, Liverpool.

P. London: Published Sept. 30th, 1836, by Ackermann and Co., and Henry Lacey, 64, Bold St., Liverpool.

Q. Milano: presso gli Editori Pietro e Giuseppi Vallardi' Conta di' Sa. Margherita N. 1101.

STATES OF THE PLATES.

1.—The Tunnel.

State 1.—"Plate 1." Pub. line A (67 mm. long). "H. Pyall, sculpt." Two figures to left, three to right. A locomotive in the distance.

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State 2.—As last, but trucks substituted for the locomotive, and hauling ropes added.

State 3.—Spanish.

State 4.—English title, etc., re-engraved. Pub. line A, 76 mm. long.

State 5.—Pub. line H (1833). The three figures to right have been removed. There is a new single figure in the foreground. The train is considerably lengthened, with heavily-laden trucks about the centre of the foreground. In this case the word "Plate" was retained all through.

2.—Entrance of the Railway at Edgehill, Liverpool.

State 1.—"Plate 2." Pub. line A (curled end to the top of L in title). "H. Pyall, sculpt." The left chimney is only about one third built, and is surrounded by scaffolding. No balustrades to stairs.

State 2.—Spanish. ("Plate" deleted).

State 3.—"2." Pub. line B (L in title not curled).

State 4.—"2." As last, but chimney complete, and scaffolding removed.

New plate. "Plate II." Pub. line F (1833). "S. G. Hughes, sculpt." Spiral lines round chimneys. Does not show opening at further end of central tunnel, nor the locomotive emerging therefrom. Balustrades; five lamps.

3.—Excavation of Olive Mount (four miles from Liverpool).
(This one is upright instead of oblong.)

State 1.—"Plate 3." Pub. line B. Title 115 mm. "H. Pyall, sculpt."

State 2.—"3." Spanish.

State 3.—"3." Pub. line B. Title 131 mm. "Four" instead of "4."

New plate. "Plate III." Pub. line F (1833). "S. G. Hughes, sculpt." The left side is similar to the previous plate. The rock wall on right is finished. Some small trees show over the bridge; there is no train going away, and another bridge is seen in the distance.

4.—Viaduct across the Sankey Valley.

State 1.—"Plate 4." Pub. line B (65 mm.). "H. Pyall, sculpt."

State 2.—"4." Spanish.

State 3.—"4." Pub. line B (69 mm.).

State 4.—"4." Pub. line J (1833).

5.—View of the Railway across Chat Moss.

State 1.—"Plate 5." Curved end to V. Pub. line B (62 mm.). "H. Pyall, sculpt."

State 2.—"5." Spanish. Plate worked up in background.

State 3.—"5." V ends in a dot. Pub. line B (73 mm.).

State 4.—"5." Pub. line J (1833).

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6.—Entrance into Manchester across Water Street.

State 1.—" Plate 6." Title reads " Bridge Street," evidently an error. Pub-line B (67 mm.). " H. Pyall, sculpt."

State 2.—As last, but title altered to " Water Street."

State 3.—" 6." Spanish.

State 4.—" 6." Pub. line A (75 mm.).

State 5.—" 6." Pub. line H (1833). No engraver's name. A tall chimney has been added at the top of the elevated water tank. Another chimney shows in the distance to the rear of train. Three figures in central foreground instead of five. Lamp post on right. No windows in house at extreme right.

The bridge shown in this print presents practically the same appearance to-day.

7.—Coaches, etc., employed on the Railway.

State 1.—" Plate 7." Pub. line B (68 mm.). " H. Pyall, sculpt."

The ss in " Passengers " both short.

State 2.—" 7." Spanish.

State 3.—" 7." Pub. line B (75 mm.). Long s in " Passengers."

State 4.—" 7." Pub. line J (1833).

8.—Railway Office, Liverpool.

This is the station at Crown Street. Since the opening of Lime Street Station in 1836 it has only been used for goods.

State 1.—" Plate 8." Pub. line D. " S. G. Hughes, sculpt."

State 2.—" Plate 8." Pub. line M (1833).

The triangular space under the roof has been boarded in on the front. The entrance to the tunnel is considerably widened, the joints in the masonry being delineated, and the railway carriages in the distance taken out. The pillar at the extreme right has been shortened, over the top of which now shows a lean-to shed. Three lamps have been added, and two notices on the wall to right.

9.—Warehouses, &c., at the end of the Tunnel towards Wapping.

State 1.—" 9." Pub. line D. S. G. Hughes, sculpt.

State 2. " 9." Pub. line K (1833).

10.—Moorish Arch, looking from the Tunnel.

State 1.—" Plate 10." Pub. line D. " S. G. Hughes, sculpt." Wide piers to arch, the characteristic contraction at the springing being strongly marked. No balustrades. Only one lamp, on the left side.

State 2.—" Plate 10." Pub. line E (1832).

The piers have been reduced, the arch being now only very slightly contracted, showing more of the bridge in the distance. Iron balustrades have been added to

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the staircases, and the platform on the first floor. Six lamps have been provided. A high wall appears at the top of the right side.

11.—Near Liverpool, looking towards Manchester.

State 1.—" 11." Pub. line D. " H. Pyall, sculpt."

State 2.—" 11." Pub. line K (1833).

12.—Rainhill Bridge.

State 1.—" 12." Pub. line D. " H. Pyall, sculpt."

State 2.—" 12." Pub. line K (1833).

There is a great deal of shading spread over the bridge, taking off the newness, and giving it a weathered appearance. This admirable bridge is in exactly the same state to-day. The plates were usually coloured by artists who were not aware that it was built of red sandstone, and depicted it as if made of grey or yellow stone.

13.—Parkside (The station where Mr. Huskisson fell).

State 1.—" Plate 13." Pub. line D. " H. Pyall, sculpt."

There is an open space behind the masonry close to the central water column. The tops of the chimneys of the old cottage (presumably utilised as station buildings) are out of repair.

State 2.—Similar to last, but title altered to " Taking in Water at Parkside."

State 3.—" Plate 13." Pub. line L (1833).

An engine shed has been built in the open space referred to above, and a tall chimney added on the right. The cottage chimneys have been repaired with neat caps.

We now come to the well-known pair of oblong plates, 26 inches by 8. Both are entitled " Travelling on the Liverpool and Manchester Railway," and depict two trains, one above the other. At the foot they are inscribed " Drawn by I. Shaw, Liverpool," and " Aquatd. by S. G. Hughes."

" Plate 1." Above the upper train, " A Train of the First Class of Carriages, with the Mail "; below the lower train, " A Train of the Second Class, for outside Passengers."

State 1.—Pub. line C. The upper train is drawn by the " Jupiter," of the " Planet " class, incorrectly shown with four equal wheels, with a comparatively modern-looking four-wheeled tender, and consists of five similar carriages, usually coloured yellow, terminated by a red one carrying the mail. The lower train is hauled by the " North Star," an improved " Rocket," with the primitive water barrel tender. There are six open carriages, crammed with passengers, the first three of which are entered by doors, and the other three by means of open spaces in the middle.

State 2.—Pub. line G (1833). The upper train has only four ordinary

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coaches, the "Royal Mail" having been moved one forward. At the rear is a private carriage on a truck, containing its owners and servants. Instead of the three carriages forming the last part of the lower train there are two like chars-a-banc, and canopies have been added to them all.

State 3.—Pub. line Q. The plate has been retouched practically all over. The titling is in Italian.

Plate 2.—Above the upper train, "A Train of Waggons with Goods, &c., &c." Below the lower one, "A Train of Carriages with Cattle." The upper engine is of the "Bury" type named "Liverpool," with coupled wheels. This engine ran on the line for some little time in the early days, but never became the property of the company. Only one engine of Bury's make was actually purchased, the "Liver" in 1832, which had small leading wheels. The lower engine is an excellent representation of the "Fury," which has a splasher on the driving wheels, and a respectable tender, with a cast iron frame.

State 1.—Pub. line C. The last vehicle of the lower train is a double-decked sheep truck.

State 2.—Pub. line G (1833). An open horse box is substituted for the above mentioned.

State 3.—Italian edition, corresponding to the third state of Plate I.

A smaller edition of the last two plates were brought out by the same publishers in 1834, measuring 17 by 9 inches. There is a copy of the second in the Science Museum, South Kensington, the title being "Railway Conveyances from Liverpool to Manchester," publication line N. The engine of the goods train is the "North Star," of the cattle train, "Jupiter."

Sir David Salomon's collection includes a large coloured lithograph with all four trains on it, published by Engelmann et fils, Mulhouse. The English imitations are legion.

The St. Helens and Runcorn Gap Railway crossed over the L. and M. at right angles by an elegant stone-faced bridge designed by Vignoles, which forms the subject of a beautiful and rare plate, measuring 17 by 10½ inches. The title is as follows:—"View of the Intersection Bridge on the line of the St. Helens and Runcorn Gap Railway, crossing the Liverpool and Manchester Railway near the foot of the Sutton inclined plane.

"Erected by Charles Vignoles, Esqre., C.E., F.R.A.S., M.I.C.E.

"Dedicated by permission to Edward Greenall, Esq., of Wilderspool, Cheshire."

Pub. line O. No draughtsman's name. "S. G. Hughes, Aquatd."

The engine of the train crossing the bridge is either the "William IV." or the "Queen Adelaide." *See ante.*

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After the L. and M. line was extended to Lime Street at the Liverpool end, which took place in 1836, a plate was issued with three views on it, drawn by S. Kelper and engraved by John Harris. The two upper ones, which are 8 by 4¾ inches, show the interior of Lime Street Station, and the new Edgehill Station, the lower one, 18½ by 6 inches, giving the front elevation of Lime Street Station.

The above comprise all the views published by Ackermann which the author has been able to discover. Unfortunately no records have been kept by the firm of the engravings they issued.

Another set of illustrations, inferior in beauty, but fully equal in interest, are a series of etchings executed and published by I. Shaw, of Liverpool, in two parts, entitled:—

"A new and complete work of the Liverpool and Manchester Railway; comprising all the most interesting views on the line of Railway, and every other object of public interest connected with it; from drawings taken on the spot expressly for the work, and engraved by I. Shaw, late of Soho Square, London.

"Liverpool: Published by I. Shaw, Post Office Place; and Grundy & Fox, Exchange St., Manchester, MDCCCXXXI.

Part 1 contains (with a description)

1.—The opening of the Liverpool and Manchester Railway, Sept. 15th, 1830, with the Moorish arch at Edgehill as it appeared on that day. (See Pl. X.)

2.—The Viaduct over the Sankey Canal.

3.—Newton Church and Village.

(Pub. line of above, "Published Jany. 1, 1831, by I. Shaw, Post Office Place, Liverpool, and Grundy & Fox, Manchester.").

4.—The "Northumbrian" engine.

(Pub. line similar, but without date).

Part 2 (also with description).

5.—Chat Moss.

6.—Olive Mount.

7.—Rainhill Bridge.

8.—"Planet" engine.

(Pub. line "Published March 13th, 1831, by I. Shaw, Post Office Place, Liverpool.).

On the back of the cover is an announcement that Part III would be published 1st May, with four more views. This does not seem to have appeared. A coloured aquatint by Havell, after a drawing by Calvert, measuring 12 by 8½ inches, was issued by some publisher unknown. It is more artistic than accurate. Title: "View of the Manchester and Liverpool Railway. Taken at Newton."

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All the following are lithographs, uncoloured unless otherwise described.

1.—A set of small ones, $5\frac{1}{4}$ by 4, were issued by W. Crane, of Chester. Those seen are:—Moorish Arch; Olive Mount; Sankey Viaduct; Newtown Viaduct; Bridge over Water Street, Manchester.

2.—Coloured lithograph of three trains, $14\frac{3}{4}$ by $8\frac{3}{4}$ inches; 1st class, 2nd class, and goods. Engines, "Northumbrian," "Jupiter," and "Liverpool."

3.—Coloured lithograph of locomotive "Phœnix" attached to a single carriage. $11\frac{3}{4}$ by $6\frac{1}{4}$ inches. These two are also by Crane, of Chester.

The pamphlet published by Cannell contains an advertisement of three lithographed views after drawings by A. B. Clayton. Probably they are the following, though published by Engelmann, Graf, and Coindet, namely, "Moorish Arch" and "Olive Mount Cutting," "on stone by Alfred Clayton," and "View of the Liverpool and Manchester Rail Road at the point where it crosses the Duke of Bridgewater's Canal." "A. B. Clayton, delt. On stone by G. F. Nicholson." Size of these three 13 by $9\frac{1}{8}$ inches.

Lithograph $25\frac{1}{2}$ by $16\frac{7}{8}$ inches. Viaduct over the Sankey Canal and Valley. Drawn on stone by W. Smoult, Civil Engr. Feb. 3, 1830. Printed from stone by George Smith, Liverpool.

16 by 10 inches. Olive Mount. Drawn by Wm. Smoult, printed by George Smith.

$28\frac{1}{8}$ by $11\frac{5}{8}$ inches. Bridge crossing the Liverpool and Manchester Railway. From a design by H. S. Merrett, Architect and Surveyor. Lithographed by George Smith.

There is an engine of the "Planet" type on the upper line, drawing a coach with "St. Helens Railway" on it.

Lithograph, 10 by $6\frac{3}{8}$ inches. A train drawn by the "Planet," with a splasher bearing the name curved in large letters, H. Austen, del. Lithd. by Baird, Soth. John St., Liverpool.

11 by $6\frac{1}{4}$ inches. Published by Thomas Kay, 30, Castle St. (Liverpool), 1838.

Railway Station at Lime Street, Liverpool (view of exterior). Drawn by R. Barrow, London; Lithographed by W. Crane, Chester.

There is also an old print, entitled the "Rocket," reproduced in Moyaux' book on medals, which appears to have been sketched from the "Northumbrian." Sundry illustrations exist in books and pamphlets of the period, among which the set of ten lithographs contained in "The Railway Companion" of 1833, published by Effingham Wilson, are worthy of special mention. One of them gives the only known contemporary sketch of the "Caledonian."

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SECTION V.—COMMEMORATIVE MEDALS, AND MISCELLANEOUS OBJECTS.

A.—Medals.

1.—Bronze and pewter. 46 mm. diam. (See Pl. XI.)

Obverse: Head of George Stephenson. Inscr., "Geo. Stephenson, Esq., Engineer."

Reverse: View of a bridge of four arches, over which a train is passing, drawn by a locomotive of the "Killingworth" type. Inscr., "Bridge at Newton, Liverpool & Manchester Railway opened Sept. 15, 1830."

2.—Silver, bronze, and pewter. 48 mm. diam.

Obverse: View of the "Moorish Arch," looking towards the original Edgehill Station. Inscr., "Entrance to the Liverpool Station & Tunnels. Published by T. Woolfield, Bazaar, Liverpool."

Reverse: View of the Sankey Viaduct with a train on it, drawn by the "Rocket." Inscr., at the top, in one curved line, "Viaduct over the Sankey Canal & Valley." Below, in five straight lines, "To Commemorate the Opening of the Liverpool and Manchester Railroad, Sep. 15, 1830. Signed Halliday, S."

3.—Pewter. 45 mm. diam.

Obverse: Between two palms, in fourteen lines, the legend, "The Liverpool and Manchester Railroad. This grand national undertaking had the Royal Assent April 12th, 1827, opened September 15th, 1830, in the presence of His Grace the Duke of Wellington and other distinguished personages." At foot, "Ottley."

Reverse: Similar to that of No. 2, but with small differences. Inscr., "Viaduct over the Sankey Canal & Valley, 14½ miles from Liverpool," in three curved lines. At foot, "G. Stephenson, Esq., Engineer."

4.—Bronze. 45 mm. diam.

Obverse: The King's head. Inscr., "William IIII ascended the British Throne June 26, 1830, in the 65 year of his age."

Reverse: As No. 3.

5.—Pewter, 45 mm. diam.

Similar to No. 4, but with the head of the Duke of Wellington instead of the King.

The following three medals were struck to commemorate the opening of the Grand Junction Railway in 1837, but also refer to the L. and M.

6.—Pewter. 49 mm. diam.

Obverse: A viaduct of ten arches, with a city behind it. Inscr.: Above, "Part of the viaduct of 28 arches at Birmingham." Below: "On the Liverpool, Manchester, & Birmingham Grand Junction Railway, opened July 4th, 1837. Signed, Halliday, F."

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Reverse: The outside of Lime Street Station. Inscr.: "New Grand Entrance of the Railway Station at Liverpool. T. Halliday, Fecit."

7.—Pewter. 55 mm. diam.

Obverse: A viaduct of 19 arches with two trains on it. Inscr.: Above, "Viaduct over the Valley of the Weaver." Below, "Published to Commemorate the Opening of the Grand Junction Railway, July 4, 1837. By W. B. Promoli, late Thos. Woolfield, Church Street, Liverpool. Signed T. Halliday, Fecit."

Reverse: Similar to No. 6, but inscr., "Grand Façade of the New Railway Station at Liverpool."

8.—Pewter. 47 mm. diam.

Obverse: View of two converging viaducts, which appear to be intended to represent the junction of the London and Birmingham and the Grand Junction lines at Birmingham. Inscr.: Above, "Birmingham, Liverpool, & Manchester." Below, "Grand Junction Railway. Begun 1835, opened July 4, 1837. Cost £1,500,000. J. Locke, Engr. Signed: "Heeley and Coy., T.W.I."

The reverse consists of a time table, giving the times at which the first class left Birmingham, Liverpool, and Manchester, and the mileage and time taken to reach eight stations from Birmingham, Liverpool, and Manchester are both given as 97½ miles, the time required being 4⅛ hours.

9.—Several medals were struck to commemorate the Stephenson Centenary in 1881, all poorly executed. One shows the "Rocket."

B.—Miscellaneous Articles.

1.—Pottery jugs, decorated with transfer representations of the railway under the "Moorish Arch," entitled "Entrance to the Liverpool and Manchester Railway." On the other side, a fanciful representation of a train drawn by the "Novelty." These are known in three sizes.

2.—A pottery jug with transfer representation of the opening procession, showing a train drawn by the "Northumbrian," with a vehicle containing a band, and the triumphal car for the distinguished visitors. Marked underneath, "Liverpool and Manchester Railway." (See Pl. XI.)

3.—Pottery mugs of various sizes, bearing transfers of a train, usually drawn by the "Fury."

4.—Plate with transfer of the "Moorish Arch." Marked "E. W. & S." "Railway." Probably by Enoch Wood & Sons, of Burslem.

5.—Cotton handkerchief, printed with a caricature showing horses dancing and playing musical instruments, entitled "Effects of the Rail Road on the Brute Creation." The border consists of the following views: A train drawn by the "Queen Adelaide"; the Sankey Viaduct; a train drawn by the "Comet"; and

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the suspension bridge on the Middlesborough branch of the Stockton and Darlington Railway.

6.—Cotton handkerchief, printed with views of the line in sepia (copied from the Ackermann prints); in the centre a representation of an engine of the "Samson" type. The main title is in English, French, and German. Probably made in Manchester.

SECTION VI.—BIBLIOGRAPHY.

Hardly a book has been written about railways which does not refer to the Liverpool and Manchester. The following list is only intended to include the more important ones dealing with the subject, omitting accounts which are merely copied from previous works, and do not add anything material in the way of information.

1824.—Letter on the projected railroad between Liverpool and Manchester: By Joseph Sandars. Liverpool: Printed by W. Wales and Co., Castle-street.

The author was one of the keenest advocates of the railway, and afterwards became a Director. This is an ably written tract of 32 pp. addressed to the Members of Parliament, to merchants, and to others interested in the conveyance of goods between Liverpool and Manchester. It gives an account of the high charges and general inconveniences of the canal system. There were at least two editions.

1828.—Report on Railroads and Locomotive Engines. Addressed to the Chairman of the Committee of the Liverpool and Manchester projected Railroad. By Charles Sylvester, Civil Engineer, Liverpool. Printed by Thomas Kaye.

This was a semi-official report, as an introductory letter, dated 15 December, 1824, addressed to the Chairman (Charles Lawrence), commences "Having been requested by a friend, a Member of your Committee, to inspect," &c. It is in favour of locomotives. There were two editions, both 1825.

1829.—Walker's and Rastrick's Reports. First Edition. Together: 500 printed by order of the Board.

Report to the Directors on the Comparative Merits of Loco-motive and Fixed Engines as a Moving Power. By Jas. Walker and J. U. Rastrick, Esqrs., Civil Engineers. Liverpool: Printed by Wales and Baines, Castle Street, 1829.

Walker's report (42 pp.) precedes Rastrick's, which is paged 43-80.

Second editions, "corrected," of both reports were published separately—Walker's by John and Arthur Arch, Cornhill, 1829 (50 pp.) Rastrick's, by R. Wrightson, Athenæum, New St. (Birmingham), with two other names in addition, 1829.

1829, &c.—The "Mechanics' Magazine" for this and the two subsequent years contains a quantity of information, not always perfectly reliable.

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It mentions that the velocity of the "Novelty" (1½ miles in 3 minutes) was so great that "we could scarcely distinguish objects as we passed by them" (17 Oct., 1829). In the number dated 31 Oct., 1829, it says that the "Perseverance" carried the boiler and furnace on a separate carriage. There appears to be a confusion here with a steam coach, as it goes on to describe the "mode of steering the front wheels." It states (19th March, 1831) that when the "Novelty" first appeared the wheels were coupled with a chain, which was found superfluous and removed.

1830.—Observations on the comparative merits of locomotives and fixed engines as applied to railways; being a reply to the report of Mr. James Walker to the Directors of the Liverpool and Manchester Railway compiled from the reports of Mr. George Stephenson, with an account of the competition of locomotive engines at Rainhill in October, 1829, and of the subsequent experiments. By Robert Stephenson and Joseph Locke, civil engineers. Liverpool: Printed by Wales and Baines.

1830.—An account of the Liverpool and Manchester Railway, comprising a history of the Parliamentary proceedings, preparatory to the passing of the Act, a description of the railway, in an excursion from Liverpool to Manchester, and a popular illustration of the mechanical principles applicable to railways. Also an abstract of the expenditure from the commencement of the undertaking, with observations on the same. By Henry Booth, Treasurer to the Company. Liverpool: Printed by Wales and Baines.

The scope of this work is fairly adequately set forth in the title. It forms the principal mine in which most subsequent writers have dug. The author suggested the multitubular principle, which was embodied in the boiler of the "Rocket" for the first time in this country. He also invented the screw coupling.

The second edition is dated 1831, in which year there was also one issued in Philadelphia.

1830.—An accurate description of the Liverpool and Manchester Rail-way—the tunnel, the bridges, and other works throughout the line: with a sketch of the objects it presents interesting to the traveller or tourist. By James Scott Walker. Liverpool: Printed and Published by J. F. Cannell, 81, Lord Street. 46 pp., folding frontispiece with lith. view of Sankey Viaduct, map, and section of the line. Published before the opening (15 Sept., 1830).

Second Edition. Enlarged, with an account of the accident. 51 pp. "Note" to second edition is dated October 1st, 1830. Frontispiece as before, with an additional lithographic view of the bridge over Water Street, Manchester.

Third Edition. There were three impressions, all differing. Instead of the previous illustrations, all have Shaw's etchings of Rainhill Bridge and Olive Mount.

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In print (a) "Third Edition" is in lower case type. Date 1831.

In (b) "The Third Edition" is in italic caps. 1831.

In (c) an account of the branch railways is added, and the title-page is dated and priced "1832, price one shilling." (The price of (b), which was on the cover only, was 1s. 6d.).

1831.—Descriptive and historical account of the Liverpool and Manchester Railway. By Joseph Kirwan. Glasgow: Published by McPhun.

A pamphlet of 32 pages, giving a good, and in places very amusing, account of the line. The frontispiece consists of a beautiful line engraving of Braithwaite and Ericsson's "William the Fourth." Reprinted in *Glasgow Mechanics' Magazine,"* Vol. V. (1834).

1831.—Description raisonnée et vues pittoresques du chemin de fer de Liverpool à Manchester. Par P. Moreau, mis en ordre par A. Notré, 98 pp., 4to, map and 2 folding plates with 9 etchings on india paper. Paris: C. Goeury.

An interesting description. One of the folding plates shows a "Planet" locomotive, the other details of rails, points, etc. The etchings are all copied from Ackermann prints, except one, which is from Shaw's illustration of the opening.

1832.—A history and description of the Liverpool and Manchester Railway. Published by Thomas Taylor, 1832.

This is a small pamphlet, 16mo, 72 pages.

1832.—A Practical Treatise on Railroads. By Nicholas Wood. Second edition.

The first edition of this work was published in 1825. The second was much enlarged, and contained a full description of the Rainhill contest, the author being one of the judges. A third edition appeared in 1838.

1832.—Liverpool and Manchester Railway.

Answer of the directors to an article in the *Edinburgh Review* for October, 1832. Liverpool: Wales and Baines.

There is some interesting information to be gathered from this reply to certain criticisms which had been made against the management of the railway. The "William IV." and "Queen Adelaide" are described as "large and beautiful engines." No goods were carried until January, 1831, owing to the unexpected rush of passenger traffic.

1832.—Remarks on the comparative merits of cast metal and malleable iron railways, and an account of the Stockton and Darlington Railway and the Liverpool and Manchester Railway, etc., etc. Newcastle: Printed by C. H. Cook, 1832 (probably 4th edition). The portions of this work relating to the L. & M.R.

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consist of a beautiful engraving of a "Planet" type engine; a short account of the commencement of the line and the Rainhill competition, together with the "Answer" of the directors just mentioned.

1833.—The Railway Companion, describing an excursion along the Liverpool line, accompanied with a succinct and popular history of the rise and progress of rail roads, illustrated by several lithographic views. By a Tourist. London: Published for the Author, by Effingham Wilson, Royal Exchange, and James Fraser, 215, Regent Street. 1833.

This is a pamphlet of 46 pages similar in character to the earlier ones by Walker and Kirwan, but in many respects more interesting. The historical sketch, which occupies half of it, is excellent, also the illustrations, which consist of five folding plates containing ten views, lithographed by E. Colyer, London. The locomotive selected for exhibition on this occasion is the "Caledonian," which appears to have been incorrectly depicted in subsequent works.

1833.—Voyage de Manchester à Liverpool par le Raill-way (*sic*) et la voiture à vapeur. Extrait d'un voyage on Angleterre pendant l'année 1831 par M. Cuchetet. Louviers: Ch. Achaintre.

A pamphlet of 25 pages.

1834.—Descriptive Catalogue of the Padorama (*sic*) of the Liverpool and Manchester Rail-road; now exhibiting at Baker Street, Portman Square. 8vo, with 12 lith. views. Printed by E. Colyer. The views are nearly identical with those in the "Railway Companion" of 1833.

The "Padorama" contained 10,000 square feet of canvas, on which the scenery at the principal points of interest was depicted, and was accompanied by "correct" models of the engines and carriages.

1835.—Description des locomotives Stephenson circulant en Angleterre et en France, etc. Avec 6 planches. Bruxelles: J. B. Champon.

This little book has been mentioned here because it contains the remarkable statement (p. 16) that recently on the L. and M. Ry. a locomotive of Sharp Roberts' ran a mile in 57 seconds, a league in 2 minutes 22 seconds, and 25 leagues an hour. As this engine must have been the "Experiment," which had vertical cylinders, someone must have been drawing the long bow.

1836.—History and Progress of the Steam Engine. By Elijah Galloway, to which is added an extensive appendix by Luke Hebert. London: Printed for Thomas Kelly.

Thirty-eight pages are devoted to the L. and M. Ry., with drawings of all the engines competing at Rainhill, except the "Perseverance."

1836.—A Practical Treatise on Locomotive Engines upon railways. By the Chev. F.M.G. de Pambour. English edition published by John Weale, London.

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An American edition was brought out the same year by Carey and Hart of Philadelphia.

This work, which had been published the year previous in French, gives the results of an elaborate series of experiments carried out by this engineer on the L. and M. Railway. It includes a description and drawings of an engine of the "Planet" type.

Second enlarged editions were published both in French and English in 1840.

1838.—Cornish's Strangers' Guide to Liverpool and Manchester, with the Traveller's Companion on the Railroad, and an accurate engraving of the line of road, a section of the line, etc.

This is a small paper-bound book of 108 pages, only 20 of which are devoted to the railway, the rest consisting of guides to Liverpool and Manchester. A similar one had been issued in 1837, which included the Grand Junction Railway as well.

1838.—The Iron Road Book and Railway Companion from London to Birmingham, Manchester and Liverpool. By Francis Coghlan. London: A. H. Bailey and Co.

This is a little book of the same nature as the last, but, as the title indicates, more extensive in scope.

1839.—A Practical Treatise on Railways. By Lieut. Peter Lecount.

An interesting early account. The author says that the "Planet" was in the Mersey, but not landed when the railway opened.

1840.—The Railways of Great Britain and Ireland. By Francis Whishaw, M.I.C.E. London: Simpkin, Marshall and Co.

An account of the L. and M. Ry. is given, together with a copy of the working regulations, and a list of locomotives in 1840.

1851.—A History of the English Railway. By John Francis. London: Longman, Brown, Green and Longmans.

Three chapters are devoted to the L. and M. Railway.

1852.—Our Iron Roads. By F. S. Williams. London: Ingram, Cooke and Co.

There is here a chapter mostly devoted to the L. and M. line, and an appendix of over 40 pages, consisting of an abstract of the parliamentary proceedings in connection with the first Bill.

A second and enlarged edition appeared in 1883.

1855.—Railway Machinery. By D. K. Clark: Blackie and Son.

The historical section contains details of the early locomotives of the L. and M. Railway.

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1857.—Life of George Stephenson. By Samuel Smiles. London: John Murray.

Contains a very full and much-quoted account of the difficulties attending the obtaining of the Act and the making of the railway. It would perhaps be untrue to say that Smiles has exaggerated the importance of the part played by George Stephenson in connection with this, the first railway as we understand the term, because that would be almost impossible; nevertheless, the fact remains that he does not give sufficient credit either to James or to Vignoles, the latter being hardly mentioned, although a considerable amount of the work was carried out by him.

1861.—The Two Jame's (*sic*) and the Two Stephensons. By E. M. S. P. London: Printed by G. Phipps.

This is a small book written to put forward the claim of William James to the title of the "Father of Railways," by his daughter. She complains that Smiles does not do adequate justice to the part he played in the early stages of the Liverpool and Manchester undertaking, which is no doubt true, but is an eager, sometimes bitter, partisan.

1862.—The Life of Joseph Locke. By Joseph Devey. London: E. Bentley.

Though Locke was one of the engineers employed on the Liverpool and Manchester Railway, there is little to be gathered from this work on the subject, it being mostly devoted to his later achievements, commencing with the Grand Junction Railway, which he constructed.

1863.—The Life of Robert Stephenson. By J. C. Jeafferson. London: Longman, Green.

This biography contains a considerable amount of information relating to the L. and M.R. not given by Smiles, especially in connection with the subjects of tubes in boilers, and the draught. A letter is quoted from George to Robert Stephenson of April, 1828, in which he proposes to turn part of the exhaust into the firebox. An engine was constructed about this time with a breeches flue, which was a failure.

1869.—Memoir of the late Henry Booth, of the Liverpool and Manchester, and afterwards of the London and North Western Railway. By Robert Smiles. London: Printed for private circulation by Wyman and Sons.

This book is interesting, but does not contain any information of special value on the subject of the railway.

1871.—Locomotive Engineering. By Z. Colburn, continued by D. K. Clark. London and Glasgow: Wm. Collins, Sons, and Co.

The early locomotives are described at the beginning of this work, and the Rainhill trial. The subjects of tubular boilers and the blastpipe are treated at some length.

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1875.—Autobiography of Sir John Rennie. London: H. and F. N. Spon.

Although the Rennies played for a time an important part in the promotion of the L. and M. Ry., the subject is only dealt with briefly. They considered that the directors treated them badly. The most interesting item of information is that if their services had been retained the gauge would have been 5 ft. 6 in.

1886.—An outline of the growth of the locomotive engines and a few early railway carriages. By Theodore West.

A set of large lithographed sheets containing hundreds of outlines of locomotives. There are only a few L. and M.

1889.—Life of Charles Blacker Vignoles, F.R.S., etc. By his son, C. J. Vignoles. London: Longman, Green and Co.

The ninth and tenth chapters consist of an account of Vignoles's work in connection with the L. and M. Railway. He made the first survey, and was appointed principal resident engineer in 1825. He resigned early in 1827 owing to disagreements with Stephenson. Immediately after leaving the service of the railway he projected a tunnel under the Mersey.

1890.—The Life of John Ericsson. By William Conant Church. London: Sampson Low.

There is an interesting chapter dealing with the Rainhill competition and the Braithwaite and Ericsson locomotives. The "Novelty" closely resembled a steam fire engine (horse-drawn), which Ericsson had built in 1828. The firm failed by 1857. In 1839 Ericsson went to the United States. Braithwaite afterwards became chief engineer of the Eastern Counties Railway.

1892.—The Locomotive Engine and its Development. By Clement E. Stretton. London: Crosby, Lockwood and Son.

Much information, not all of it accurate, is conveyed in the early part of this work on the subject of L. and M. engines. It includes a list of them down to 1836.

1898.—The Evolution of the Steam Locomotive. By G. A. Sekon.

This is an interesting book, comprising some useful information. Like Stretton's, it is for popular consumption. A second edition appeared in 1899.

1905.—Les Chemins de Fer autrefois et aujourd'hui et leurs médailles commémoratives. Par Auguste Moyaux. Brussels: Ch. Dupries.

This magnificent work deals primarily with the subject of railway medals, of which, including those given in a supplement published in 1910, some seven hundred are described. It commences with a delightful historical section, accompanied by interesting illustrations. There is a reproduction of an old print of the Rainhill competition, which gives, in a sketchy form, perhaps the only known delineation of the "Perseverance."

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1914.—The History of the London and North Western Railway. By Wilfred L. Steel. London: "The Railway and Travel Monthly."

The first chapter gives an account of the L. and M. Railway. It includes a few details of interest not given by Smiles.

There is, of course, much information scattered about in the old files of the engineering press, especially in back numbers of *The Engineer*. A valuable series of articles appeared from time to time in that journal entitled "Links in the History of the Locomotive," the most important, dealing with the L. and M. Ry., being in the numbers of the following dates: 30 June, 1876; 17 Sept., 1880; 18 March, 1881; 23 Feb. and 2 March, 1883. A fierce and wordy warfare on the subject of the blast pipe was waged from July to October, 1857. During 1884 and 1885 there was much correspondence on the subject of the "Rocket."

In conclusion, the author desires to express his cordial thanks for kind assistance to Sir David Salomons and Mr. E. L. Ahrons; to Captain Beames and Mr. Graseman, of the L. and N.W.R.; Mr. J. G. H. Warren, of Messrs. Robert Stephenson and Co.; Mr. H. W. Dickinson and Mr. E. A. Forward, of the Science Museum, South Kensington; Messrs. Shaw and Robertson, of the Public Library, Liverpool; Messrs. Ackermann and Son and Messrs. Rimell and Co., of London; and Messrs. Henry Young and Sons, Liverpool.

Mr. Dendy Marshall contented himself by reading an abstract[1] of the above paper, which was available to members at the meeting, and then went on to draw attention to the principal features of interest in the engravings, articles of pottery, medals, etc., that he had brought from his private collection and arranged in the room. With these were a model of a "Planet" type locomotive shown by Mr. Lowy (Member), and models of the "Rocket" and "Northumbrian," kindly lent by Mrs. Knight of Farnham. A Liverpool and Manchester coke sheet of 1842 was shown by Mr. Ahrons (Member). Illustrations of a few of the objects are given (pl. IX. to XIII.)

After an interval, to give members an opportunity of examining these objects closely, a vote of thanks to the author was moved by Mr. W. A. Young, seconded by Sir George Greenhill, and carried by acclamation.

Discussion.

Mr. Young said he was specially struck with the useful bibliography. Sir George Greenhill claimed to be a link with the period under discussion, as he had known John Braithwaite personally. Sir George gave some reminiscences of the latter, and mentioned that his works were in New Road (now the Euston Road). The engine "Novelty" was named after a theatre. The name

[1]This abstract appeared in "The Engineer," November 18th, 1921.

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"Rocket" was the outcome of a barrister's would-be jibe: "People would as soon mount one of Colonel Congreve's rockets as one of these railway coaches."

Mr. S. Russell remarked that the link motion had been claimed for Ericsson,[2] as well as for Howe. In this connection Mr. D. Brownlie said there was an engine at Clay Cross still in existence that had on it one of the earliest link motions by Howe.

Mr. Lough Pendred thought the two locomotives "Lancashire Witch" and "Twin Sisters" were of great interest, and he would like to know more about them. The derivation of the word "clinked" in the expression "tubes are clinked" required explanation.

Mr. Rhys Jenkins said this came from the same root as clinch.

Mr. R. Young felt inclined to doubt the statement that the "Swiftsure," of Forrester, was the first locomotive with outside horizontal cylinders, but he was not prepared with definite evidence on this point.

Mr. E. A. Forward said that Liverpool and Manchester made the railway, and the railway practically made the locomotive. Adverting to Mr. Pendred's remarks, he said that of the "Lancashire Witch" and "Twin Sisters" little was known, but they were forerunners of the "Rocket." All three owed their inception more to Robert than to George Stephenson. The original construction of the firebox in the "Rocket" was still doubtful, but all the evidence pointed in one direction. He doubted the square smoke-box of the "Northumbrian." As regards boiler tubes, ferruling and beading over were possibly hit on almost at once. Simon Goodrich recorded, on March 26th, 1830, when at Stephenson's works, that "an iron ferrule is inserted into the end of each pipe and rivetted with it into the boiler end." The "Planet" was the greatest single step in progress, and all succeeding engines followed on its lines.

Eng. Capt. E. C. Smith said he had no experience of locomotive boilers, but in marine boilers the leaky tube was ever present. He had records, in the early days, of dung, potatoes, or even a sack of oatmeal being put into the boiler to stop leakage! He found that the diameter of tubes at this period increased according to the size of the boiler.

Mr. A. Legros, Mr. J. Russell, Mr. Lancaster Burne, and Mr. Butt-Gow also joined in the discussion.

The author, replying, said that the statement about Ericsson and the link motion could not be substantiated. As to outside horizontal cylinders,[3] he must

[2]Church. Life of John Ericsson. I. 62.

[3]This statement, in the abstract of the paper published in "The Engineer," gave rise to some correspondence, but elicited no further facts.—Ed.

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let the statement stand till evidence to the contrary was forthcoming. He agreed as to the important influence on design of the "Lancashire Witch" and "Twin Sisters." He was unable to add anything about the evolution of the firebox; the square smoke-box on the "Northumbrian," shown on the jug (Pl. XI), was probably taken from the engraving, and so, perhaps, did not add to the evidence. As regards the diameter of locomotive boiler tubes, he believed they had only varied within narrow limits.

Fig. 3.—Common Seal
of the Liverpool and Manchester Railway Co.
Actual size.

The block for the illustration of the Jug, Pl. XI., has been kindly lent by the Editor of "The Engineer"; that of the locomotive "Liverpool" by the Editor of "The Locomotive Magazine."

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Greek and Roman Engineering Instruments.

By R. C. Skyring Walters, B.Sc., Assoc.M.Inst.C.E.

(*Read at King's College, Strand, W.C., Dec. 15th, 1921.*)

Introductory.

The object of this paper is to give some account of the ancient field instruments, used by a fine race of engineers, for setting out such works as roads, canals, sewers, tunnels, harbours, reservoirs, and aqueducts, the remains of which are still to be seen in more or less good condition. So far as is known, only part of one of these old surveying instruments is in existence, but accounts of their use and construction, which have come down to us, remain. There are, moreover, many contemporary references to them. Thus, Frontinus (A.D. 100), engineer of the Roman water supply and sometime Governor of Britain before Agricola, alludes to them; Vitruvius (B.C. 25) gives practical reasons why he prefers some to others; and the Greek Heron, or Hero of Alexandria (between B.C. 100 and A.D. 100) wrote a text-book on the subject, describing an instrument called the "Dioptra."

Hero's Book on the "Dioptra."

There are three existing MSS. of this book; one in Paris, one at Strassbourg, and one at Vienna, which is incomplete. Part of the text was published by Venturi[1] in Italian in 1814, a full text in French by Vincent[2] in 1858, and a third in German by Schöne[3] in 1903. There is also a short description by Truesdell in the American *Journal of the Association of Engineering Societies*, 1897, and the author gave extracts in a paper read at a students' meeting at the Institution of Civil Engineers in 1914. Many little practical details are given that prove this ancient writer not only knew his job, but wrote his descriptions with the instrument before him. The following passages are a free translation, from M. Vincent's version, of the introductory paragraphs:—

"It is easy to say in a few words what the application of the Dioptra does in the way of solving many practical problems. Thus, it is advantageously employed for the setting out of water-channels, ramparts, harbours and buildings of every kind. It is used for many astronomical purposes in connection with the observa-

[1] "Il traguardo di Erone" (Bologna, 1814).
[2] "Le traité de la Dioptre de Héron d'Alexandrie" (Notices et Extraits des Manuscrits de la Bibliothèque Impériale, Vol. XIX., 1858).
[3] "Heronis Alexandrini Opera," Vol. III. Teubner, 1903.

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tion of the sky, such as the measurement of distances which separate stars, their size, and the determination of the distances and the eclipses of the sun and moon. Again, it is used for geographical or surveying purposes, and for the determination of the relative positions of islands and seas and, generally, for the estimation of distances between inaccessible points.

"It is useful to know a distance over inaccessible ground, for often an obstacle stands in the way which prevents us from measuring it directly, such as an enemy in possession of the country, or inaccessible or impassable land having some physical peculiarity such as a rapidly flowing river. How many times in an attack of a stronghold have we arrived at the foot of the ramparts and found that we had made our ladders and other necessary implements for the assault too short, and have consequently been defeated simply for not knowing how to use the Dioptra for measuring the heights of walls; such heights having to be measured out of the range of the enemy's missiles."

The Description of the Level and Staff.

The construction of the Dioptra is as follows—Fig. 4:—

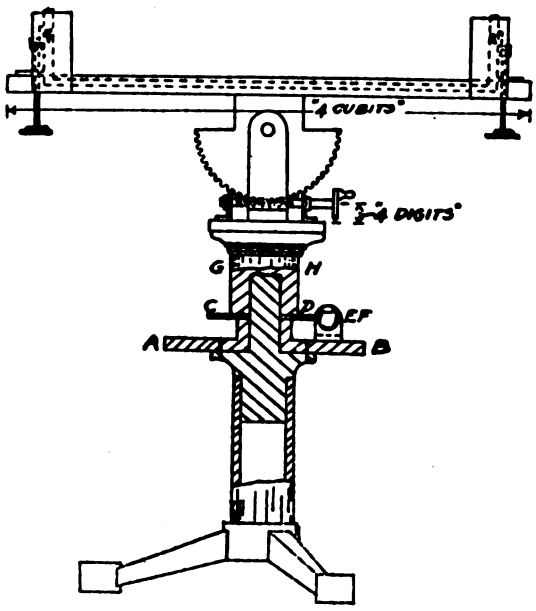

Fig. 4.—Dioptra of Hero of Alexandria, Based on the restoration of Vincent.

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A stand is made resembling a small column which has on the top a cylindrical pivot. On this pivot is fixed, concentrically, a small circular copper plate. Higher up the pivot is a copper sleeve which turns easily on it; at the bottom, this sleeve is fixed to a toothed wheel which is smaller than, and rests upon, the copper plate; and on the top, for appearance, is a plinth of a small Doric column in the form of a miniature capital. Gearing with the toothed wheel is a small worm whose bearings are fixed to the copper plate.

A groove wider than the width of the teeth is cut in the worm so that if one turns the latter until the groove is opposite the teeth, the toothed wheel will be quite free to turn; and having thus put the wheel roughly in position, the worm can be turned until its thread gears with the teeth of the wheel, which is thereby locked[4].

On the plinth, two vertical uprights, made of copper, are fixed at a distance equal to the thickness of another toothed wheel whose axle passes through them, and on the same plinth between these two large uprights is a movable worm[5] . . . whose small bearings are attached to the plinth. Between these two parallel uprights is the axle, four digits (3in.) above the top of the plinth.

In the space between the uprights there is a long rod or alidade, four cubits (6ft.) in length, supported at the middle, of the necessary width and depth. At the top of the alidade is cut a semi-circular or rectangular groove large enough to take a copper tube about twelve digits (9in.) shorter than the alidade—Fig. 5.

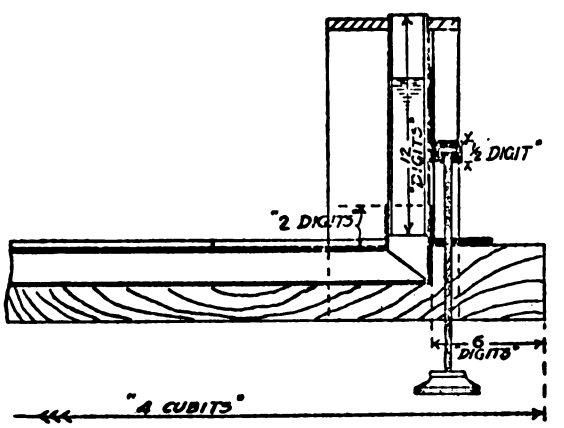

Fig. 5.—Water Level of the Dioptra,
Based on the restoration of Vincent.

[4]Comparable to the clamp of modern instruments.
[5]There is a gap in the manuscript here. Supply "to turn the toothed wheel in a vertical circle."

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At each end of this, another tube, two digits (1⅛in.) long, is fixed at right angles, which appears to be only a bend of the former. A piece of wood, fitting upon the groove, holds the copper tube tightly in place and makes a neat job. In each bent-up end is a small glass tube, about twelve digits (9in.) high, of such a diameter to fit into the copper tube, the connection with the latter being made water-tight with wax or some such material.

Two small boxes are attached near each end of the alidade to support and fix firmly the glass cylinders which go through them, and they have grooves cut in their sides for metal plates to slide up and down. These sliding plates touch the glass cylinders, and they have apertures for looking through at their centres. Small cylinders, about half a digit (⅜in.) high, are fastened to the bottom of the plates in each of which a copper rod engages. This rod is equal to the height of the box supporting the glass tube and goes through a hole in the alidade, and has a screw thread cut on it which gears with a small piece attached to the alidade.

Then if we turn the head of this (vertical) rod, we will, by this means, move the sliding metal piece, with the aperture, up or down, for the metal piece end of the rod is provided with a little cap which turns in a groove on the inside of the little cylinder.

Having described the construction of the Dioptra, we will now speak of the staves and discs which accompany it—Fig. 6.

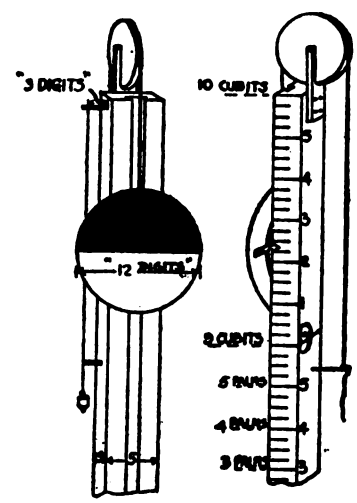

Fig. 6.—Levelling Staff of Hero of Alexandria, Based on the restoration of Vincent.

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Two pieces of wood are cut which are ten cubits (15ft.) long, five digits (3¾in.) wide and three digits (2¼in.) thick. In each is cut a dovetailed groove down the whole length of the broad side, the short side of the dovetail being outside. In this groove a tenon runs freely without coming out, carrying a circular disc ten or twelve digits (7½ to 9in.) in diameter, which is divided by a straight line, perpendicular to the length of the rod, into two semi-circles, one of which is painted black, the other white. To the tenon is attached a cord which passes over a pulley on top of the staff and goes down the other side of the staff remote from that of the disc.

Now, if one holds the staff in a vertical position and pulls the cord from behind, one makes the disc rise; if, on the contrary, one loosens the cord, the disc will descend by its own weight, especially if there has been nailed a plate of lead at the back of the disc, for this will cause it to move more quickly. Consequently, by means of the cord, the disc can be manipulated to any desired part of the staff. It is necessary to divide the length of the staff, from the bottom, into cubits, palms and digits[6]. At these divisions lines are drawn on the side of the staff to the right of the disc. The disc carries a pointer on the back in line with the diameter, which points to the graduated divisions marked on the side of the staff.

The staff must be held in a truly vertical position. This is ensured by there being fixed (on the plain side opposite the graduated side, *i.e.*, the left side of the disc) a small rod about three digits (2¼in.) long, at the end of which is a vertical hole, through which a string passes carrying a weight. Near the bottom of the staff is another small rod of a length equal to the distance of the hole from the staff on the top rod, and on the end of this is marked a vertical straight line. When the plumb-line coincides with this line it will show that the staff is truly vertical[7].

Levelling.

The following description of Hero's is quoted *in extenso*, as it must have been applicable to the alignment of ancient aqueducts whose lengths totalled hundreds of miles:

"Let B be the source of the water and A the place to where it is to be brought. At A place one of the staves A C, set up the Dioptra as far as possible from A in the direction of B, so that the staff A C can just be seen, and turn the alidade (which carries the glass cylinders) until it points to A C. Then by turning the

[6] 1 cubit = 17¼ in.; 1 foot = 11¼ in.; 1 palm = 2¾ in.; 1 digit = ¾ in.
[7] Comparable to a modern plumb rule.

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screw which is inserted in the alidade, raise the metal plates until the apertures are opposite the lines of the surfaces of the water contained in the glass tubes. The metal plates being in this position, look through the apertures in them and have the discs on the staff A C raised or lowered until the line which divides the black half from the white is seen.

" Leaving the Dioptra thus, go round to the other side of it, and sight on to another staff which is as far as possible from the Dioptra, and again set in line the dividing line of the discs of the staff. Let D E be the second staff, F the Dioptra, C and E the points determined by the line of sight of the Dioptra, D the point where the second staff is placed on the heights A C and D E are noted, suppose A C is six cubits and D E two. Then in the two columns headed ' Backsight ' and ' Foresight ' write ' 6 ' in the Back column and ' 2 ' in the Fore.

" The staff D E being kept in position, the Dioptra is set up at G, and a distance D H = 4 is read as a backsight and a distance 2 on the foresight stave. The process being continued till B is reached, all the backsights and foresights are added up, the difference being found to be, say, ten cubits. Now, as the sum of the backsights (*i.e.*, a number which represents the ground in the direction to where the water is to be led) is greater, the water will flow; for at B the ground is ten cubits higher than at A.

" As to the intermediate places over which we propose to conduct the water, we shall get their levels relative to each other or to the end places, in exactly the same method by treating any given point as if it were one of the end places. Having made these calculations for the whole length, the gradient must be found at every point, and marked levels, bench marks, put in at various points, so that there shall be no error anywhere on the job.

" The aqueduct must not necessarily be taken along the same route as the levels, for there is often a better one, depending on circumstances; such as avoiding a hill which is too steep, or composed of too hard a stone; or ground of a soft porous or sulphurous nature, or other matter which affects the quality of the water; such must be avoided."

Frontinus's book on the water supply of Rome[8] gives an interesting description of the aqueducts themselves. He says:—

" I had also plans made of the aqueducts from which it may be seen where there are valleys and how wide they are, and where rivers have been crossed; also, where the conduits laid on the hill-sides need an extended and continuous care for their protection and maintenance. In this way we reap the advantage, as it were, of having the works referred to before us and in being able to study them as though we stood by their side."

[8]Translated by C. Herschel. Longmans, 1913.

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Vitruvius, in his "Seventh Book on Architecture,"* with reference to aqueducts, speaks of levelling apparatus—Fig. 7:—

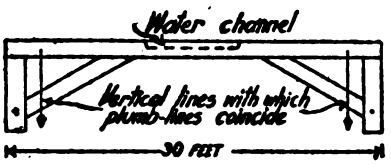

Fig. 7.—CHOROBATES OF VITRUVIUS,
As restored by Newton.

"I shall now describe how water is to be conveyed to houses and cities, for which purpose levelling is necessary. This is performed either with the Dioptra, the water level, or the Chorobates. The latter apparatus is, however, the best, as the Dioptra and level are often found to be incorrect. The Chorobates is a rod twenty cubits (30ft.) in length, having two legs at its extremities of equal length and dimensions and fastened to the ends of the rod at right angles with it. Between the rod and the legs are cross pieces fastened with tenons, whereon vertical lines are correctly marked, through which corresponding plumb-lines hang down from the rods. When the rod is set, these will coincide with the line marked, and show that the instrument stands level. But if the wind obstructs the operation and the lines are put in motion, so that one cannot judge by them, let a channel be cut on the top of the rod five cubits (7ft. 6in.) long, one digit ($\frac{3}{4}$in.) wide, and half a digit ($\frac{3}{8}$in.), deep, and let water be poured into it. If the water touch each extremity of the channel equally, it is known to be level. When the Chorobates is thus adjusted level, the inclination may be ascertained."

Vitruvius's criticism is a little misleading, for we might just as well say that a builder's straight-edge with level is more accurate than the Dumpy level or boning rods. The straight edge and level is intended to be used over small distances and the dumpy or boning rods over large ones.

Such instruments must have been used long before the time of Hero; thus in his preface he says that the Dioptra is an improvement upon previous instruments.

There are many examples of large ancient engineering works which required precise levelling: such as the canal between the Nile and the Red Sea, open B.C, 250, after 600 years' construction; the canal through Mount Athos. six miles long, cut by Xerxes, B.C. 480, probably the most famous as well as the most

*Gwilt's English version. Crosby, Lockwood, 1860.

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ancient of ship canals. Traces of it are still visible. An interesting example is that of the canal at Corinth, projected by Periander, B.C. 600; 650 years later, in the time of Nero, his engineers came to the conclusion that the canal could not be dug, as the sea was higher on one side of the Isthmus than on the other, and consequently would wash away the island of Aegina.[10]

ALIGNMENT.

Hero's description of the Dioptra and its use for levelling is immediately followed by problems of setting out lines at right angles to each other. They refer to what seem to be modifications of the same instrument which have not been described above, namely, to a large horizontal circular plate which is attached to the vertical circle—Fig. 8. This large circular plate was divided by two lines at right angles for ordinary setting out and surveying, and into 360 deg. for the measurement of angles between stars.

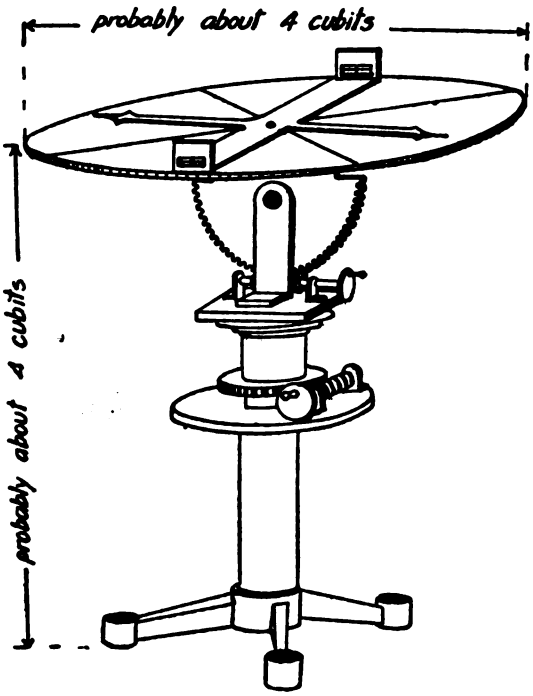

Fig. 8.—DIOPTRA OF HERO OF ALEXANDRIA,
When used for setting out lines at right angles.
Based on the restoration of Vincent.

[10]The thanks of the author are due to Professor C. Flamstead Walters, M.A., for the correctness of the facts from the classical writers embodied in this paper.

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Further, a sighting apparatus rotated about a pivot at the centre of the plate, which Schöne has called a simple alidade, thereby replacing the water level with its sighting strips; but this is quite unnecessary, as the levelling apparatus with its sighting strips described above could have been used quite as well, for the glass tubes could have been taken out and this explains the necessity for making a temporary joint with wax between the glass and copper tubes.

Hero's twenty problems are minute in detail both as regards the setting up of the instrument and the method of carrying out the work in the field, and show clearly the construction of the different parts, which has been a great help in the reconstruction of the apparatus, Hero's original drawings not being existence.

The applications may be grouped as follows:—

(1) The setting out of a connecting line between two points which are invisible from each other.

(2) The determination of a horizontal distance from an inaccessible point, distances between inaccessible points, breadths of rivers, &c.

(3) Setting out horizontal distances by means of a graduated pole placed near the instrument and sighting on to it by turning the alidade in the vertical plane by means of the vertical half circle.

(4) The determination of the heights of inaccessible points above the horizontal, heights between inaccessible points, heights of ramparts, depths of ditches, valleys, &c.

(5) Tunnelling, Straight and Curved.—The tunnels are bored from both ends "so that the workmen will meet each other," or from many places at once by shafts. That tunnels were driven simultaneously from both ends is proved by the Shiloah tunnel (580 yards), built by Hezekiah in B.C. 700; the tool marks run in opposite directions from both ends until about the middle. A notable tunnel was dug—B.C. 600—for bringing water to Samos from a spring in a hill a mile away. This tunnel was 8ft. square, with a trench 2ft. wide having a varying depth up to 30ft., because the slope of the tunnel was not the same as the trench in which the pipes were laid. It was constructed, Herodotus tells us, for Polycrates by Eupalinus, a contractor of Megara. A water-supply system in clay pipes, without tunnels, was constructed by the same firm a few years later at Athens. At Naples there was a road tunnel 2,316ft. long, 22ft. wide, and 89ft. high. Lake Fucino drainage to the Liris, three miles through hard rock, was also a wonderful undertaking for the time.

(6) Hero also deals with the setting out of harbours and curved structures, arches, &c., by bolting a template of the shape required on to the horizontal circle, tilting it to the required angle and with a pole, using the template as a sort of boning rod.

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(7) Measurements of areas both accessible and inaccessible are dealt with.

(8) Angular distances between stars and distances between two places such as Rome and Alexandria depending upon astronomical observations and some "Records," the equivalent of our Nautical Almanack; the latter is the only problem that has not been satisfactorily elucidated by either Venturi, Vincent or Schöne.

Hero only once mentions the *tape*, in connection with curved tunnels: "It must not stretch on pulling nor contract with moisture."

THE GROMA.

Nearly all the setting out and surveying done by engineers in the time of Hero depended upon right-angled triangles; consequently, the whole of the efficiency of the work depended upon an instrument to give right angles quickly and accurately. As Hero criticises unfavourably another instrument which he calls the "star"—it seems that the Dioptra was not by any means exclusively used by the Greeks, and it is known that the Roman surveyors ("Gromatici") used an instrument called the "Groma." It is very probably that the "star" and "groma" are one and the same instrument. Scholars have not satisfactorily reconstructed the instrument, but as it is of some importance the following facts are put before the members about the instrument, with a suggested drawing of it—Fig. 9.

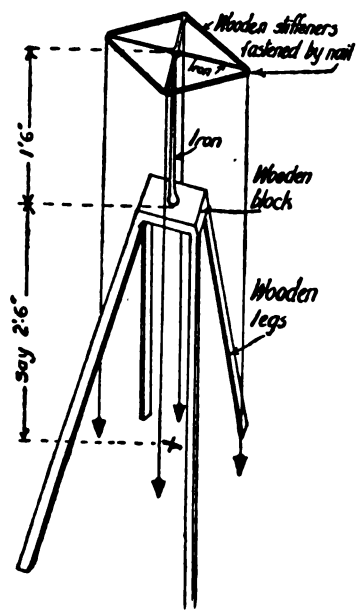

Fig. 9.—GROMA,
As reconstructed by the Author.

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It is alluded to as the Groma, or Ferramentum (iron) in books describing military operations and the setting out of fortifications, *e.g.*, Hyginus[11]. At the entrance of the headquarters of the staff half-way along the main road, there is a place called the " Place of the Groma "—because of the crowd which gathers there. The Groma is set up on its iron stand with its plumb-lines in position so that the entrances to the fortifications may be seen from the ' star ' when the straight lines connecting them are set out. Experts in this art are called Gromatici, for the reason given above."

From what Frontinus says in the " Gromatici Veteres," it is thought to be a movable plate pivoted on to a stand.[12] At the four extremities of two diameters hang plumb-lines, which were sighted in line, the instrument being used for setting out lines at right angles. He says: " To use the instrument we must steady all the plumb-lines and look at the cords or strings stretched by the weights, setting them in a line until the eye sees the nearest only. Then put in the stakes, and having carried the apparatus to the last stake, set it up as before and look at the stakes in the opposite direction by way of a check. Then, to continue the staked out line when intercepted by obstacles, carefully set out the right angles given by the plumb-lines by perpendicular lines at every point of interception."

Hero's condemnation is as follows: " Many people use the so-called ' star ' a great deal for a few of the operations performed by the Dioptra, and if we have occasion to use this instrument for the carrying out of such operations, the theory of its use is given here, so that people may not make mistakes through ignorance. I think that those who use this apparatus find serious inconvenience which results from the plumb-lines not coming to rest quickly, but continue to swing about for some time, especially with a high wind. This is why some people have tried to use wooden tubes to protect the plumb-lines from the wind. But the plumb-bobs, in consequence of touching the sides of the cylinders, do not hang truly vertical."

But even if the lines have come to rest and are perpendicular to the horizon, the planes containing the lines are not always at right angles to each other, and consequently it follows that the operation will not be performed correctly. This will be seen as follows—Fig. 10:—

Let there be two lines in a plane, A B and C D, which do not cut each other at right angles, and let A E D be an obtuse angle. At the point E erect a line E F which is at right angles to the plane containing A B and C D; it is therefore perpendicular to both the lines A E and E C. Now the angle A E C is the inclination of the plane A E F to the plane C E F, and is an acute angle.

[11] " Hyginus Gromaticus de munitionibus castrorum.' ' Gemoll (Teubner), 1879.

[12] C. Germain de Montauzan. " La Science et l'Art de l'Ingénieur aux Premiers Siècles de l'Empire Romain." (Paris, 1919.) An excellent little book to which the author is very largely indebted.

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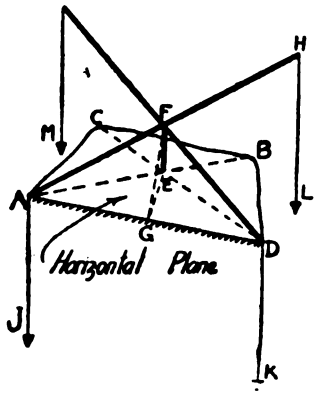

Fig. 10.—Diagram Based on Hero's Description of the "Star."

Make A E = E D. Join A D.

Drop the perpendicular E G on to it, making G A = G D.

As both these lines are greater than G E (the angles at G being right angles), it is possible to make G F = G A.

Join A F and D F.

∴ The angle A F G = D F G = 45 deg.

Produce A F and D F to H and I respectively.

Then A H is perpendicular to D I.

Draw A J, D K, H L, I M parallel to E F.

If we suppose that the arms of the star are A H and D I, and the plane containing the lines A B, C D is horizontal and the strings hung at A J, D K, I M, H L, then the plane containing A J and H L (that is, A B) is not perpendicular to the plane containing D K and I M (or D C), for these planes were made inclining to each other at an angle A E C, which is an acute angle.

The remains of an actual Groma were discovered in Bavaria,[13] consisting of a central rod 18in. high and four cross arms 9in. each. The four ends of these rods are turned down, drilled, and a long nail inserted in each hole—Fig. 11. An interesting discovery of a Roman tombstone[14] was made at Ivrea, near Turin, of a certain Aebutius Faustus, "Mensor," *i.e.* a surveyor—Fig. 12. On it is represented a design, most probably, the Groma. There are only two plumb-bobs shown, however, and the stone where the ends of the cross pieces are is worn down. The character of the lettering bears the date of the tombstone as early in the first century, and that it was made in the lifetime of the surveyor is shown by the letters "V.F.," which stands for *Vivus facit.*

[13]Schöne, Jahrbuch des Archaeologischen Instituts, 1901. (Berlin.)
[14]Gazzera, Accad. di Torino, Serie II., Vol. XIV.

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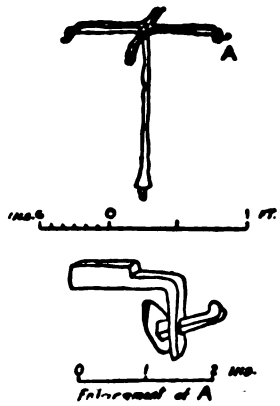

Fig. 11.—Remains of Groma
Discovered in Bavaria.

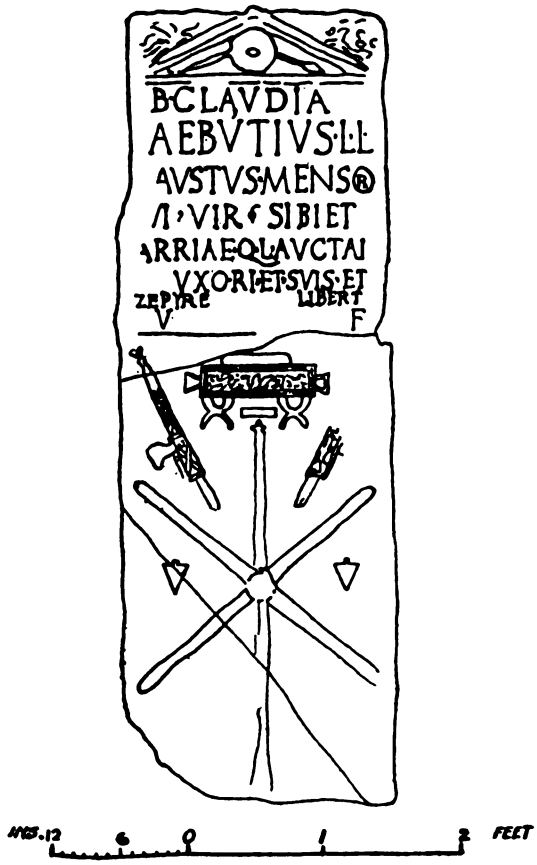

Fig. 12.—Groma,
Figured on a tombstone, Discovered near Turin.

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Summing up, we have seen that setting out and surveying up to about A.D. 100 was carried out by the Greeks and Romans with the Dioptra, Chorobates and forms of water level for levelling; and by the Dioptra and Groma for all kinds of surveying and the setting out of lines and lines at right angles to each other. We have also seen that there are many striking points of similarity not only in instruments but in the methods employed 2,000 years ago with those of the present day. Modern refinements may be necessary for modern requirements, but the old were evidently efficient enough for the erection of those beautiful structures the remains of which we see standing to-day.

The author illustrated his paper by upwards of 50 slides showing ancient Greek and Roman works of engineering. These slides had been kindly lent by the Hellenic Society, whom he thanked for their generous loan. A number of photographs from the collection of Prof. Flamstead Walters were also shown. Diagrams prepared by the author have been reproduced in the text.

On the motion of the President, a vote of thanks to the author was carried by acclamation.

DISCUSSION.

The President enquired if the method of dividing the circle of the dioptra was known, and what its accuracy was.

Prof. M. T. M. Ormsby (King's College) said it was new to him to find out how advanced were surveying instruments at so early a date. The chorabates appeared to fulfil the purpose of the builder's straight-edge.

Prof. L. H. Cooke (Royal School of Mines) said he had nothing but admiration for the work of these ancient surveyors. Apparently the dioptra served the purpose of the modern theodolite except that, obviously, for lack of an optical system, the range could not be large. The earliest reference he had found to what was essentially a theodolite was in 1571, and that was of German origin. Prior to that, everything must have been done by laying out right angles.

Mr. E. A. Forward thought that the existence of the screw adjustment pointed to a simple way of producing such screws at this time; it was a subject to be followed up.

Mr. W. H. Thorpe said he gathered that curves were set out by right angled offsets, or by templates. Had the author reconstructed an actual dioptra?

Mr. A. Honeysett wished to know what kind of accuracy was obtained in the field with these instruments, *e.g.*, in grading an aqueduct, or driving a tunnel. He thought accuracy unattainable without optical means. He enquired if the ancients had boning rods.

The author, in reply, said so little of the literature of surveying of the Greeks

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and Romans had come down to us, that information was lacking as to the division of the circle, and as to screw production. The chorobates was comparable to the builder's straight edge as Prof. Ormsby inferred, while the dioptra was used for extensive surveying and giving levels far apart. The degree of accuracy obtained could be judged by the fact that aqueducts were built with one uniform grade from the hills into Rome. As to curves for tunnels, the method consisted in setting out triangles, not necessarily right-angled, both above and below ground; but for laying out curves on the ground, from the extraordinary description given by Hero, the method was to bolt templates on to the horizontal plate of the dioptra and "bone in" these curves. He states that such curves were set out, thus, for harbours and arches, and the author suggested that this method may also have been used for the excavation necessary for the beautiful amphitheatres of which many examples had been shown on the screen that evening. As an example of a bad blunder made in setting out a tunnel in Africa in the second century (this mistake not being due necessarily to a faulty instrument, as a similar mistake had been made on a London tube in the 20th century) the author quoted the following passage given by Clemens Herschel's edition of Frontinus, viz.:—

A report (A.D. 152) of Nonius Datus, hydraulic engineer of the 3rd Legion to the Magistrates of Saldae, Algeria. After meeting with brigands on the way, who stripped him of his clothes and wounded him, he reached Saldae and, after a rest, went to the tunnel accompanied by the Governor. The report continues:

"I (*i.e.*, Nonius Datus) found everybody sad and despondent. They had given up all hopes that the two opposite sections of the tunnel would meet because each section had already been excavated beyond the middle of the mountain. As always happens in these cases, the fault was attributed to me, the engineer (*i.e.*, Nonius Datus), as though I had not taken all precautions to insure the success of the work. What could I have done better! for I began by surveying and taking the levels of the mountain; I marked most carefully the axis of the tunnel across the ridge; I drew plans and sections of the whole work, which plans I handed over to Petronius Celer, the Governor of Mauritania; and to take extra precaution, I summoned the contractor and his workmen and began the excavation in their presence with the help of two gangs of experienced veterans, namely, a detachment of marine infantry and a detachment of Alpine troops. What more could I have done? After four years absence, expecting every day to hear the good tidings of the arrival of the water at Saldae, I arrive; the contractor and his assistants had made blunder upon blunder. In each section of the tunnel they had diverged from the straight line, each towards the right, and had I waited a little longer before coming, Saldae would have possessed *two* tunnels instead of one!"

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We are told that Nonius Datus re-surveyed the work and put in a transverse tunnel connecting the two tunnels, which operation must have been skilfully done with the instruments above described.

The author said he had not constructed a dioptra from the measurements given by Hero, but hoped to do so.

Note on the Groma.

(Communicated by the Author.)

Since the above was written, Matteo Della Corte has published[1] a complete account of a Groma found at Pompeii in 1912. The remains consist of an iron cross-piece with four arms, about 18 inches long, at right angles to each other; four bronze plumb-bobs; three bronze socket pieces; two thin bronze strips, and a stout iron shoe. Associated with these remains was decayed wood.

M. Della Corte has carefully examined the parts, and he has reconstituted the instrument in a drawing herewith reproduced (Pl. XIV.). It will be seen that his reconstruction satisfactorily disposes of the difficulty pointed out in the paper, namely, the interference with the plumb lines of the supporting pillar. It will be seen that such interference did not actually occur, because there is a horizontal bracket or "Rostra" on which the cross-piece is socketed at an eccentricity of about 10 inches with the main pillar; the total height of the latter is suggested as being about 6ft. 9in.

He goes into the question of the setting up of the instrument, and the errors which may be involved if it is not set up perfectly plumb, and by the pillar being situated 10 inches away from the station; he points out that the four plumb-bobs of two different shapes were worked in pairs for surveying, one pair representing the "Cardo," the north-and-south line; and the other pair "Decumanus," the east-and-west line. He reproduces the tombstone of Fig. 12, and refers to Hero's remarks (*c.f.* Fig. 10), but doubts whether the Bavarian Groma, Fig. 11, is a true Groma.

[1]Monumenti Antichi, Accademia dei Lincei, Vol. XXVIII., 1922.

N.B.—Blocks for Figs. 4 to 12 have been kindly lent by the Editor of the "Engineer."

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Mechanics and Engineering from the time of Aristotle to that of Archimedes.

By T. East Lones, M.A., LL.D., B.Sc.

(*Read at Caxton Hall, Westminster, Jan. 24th, 1922.*)

In the history of the civilised world there have been periods remarkable for the relatively great progress made in the acquisition of knowledge. Such periods have usually been indefinite as regards the times of their commencement and termination, but every one of them presents a series of names of men of superior ability to whom the advancement of knowledge during the period was mainly due. During one of these periods Aristotle and Archimedes lived, the one well-known as a philosopher and daring pioneer in many branches of learning, and the other a geometrician and engineer. The time from the birth of Aristotle in 384 B.C., to the death of Archimedes at the capture of Syracuse, 211 B.C., was one of great historic interest covering, as it does, the subjection of Athens, Thebes and other Greek States by Alexander, the destruction of the Persian Empire, the breaking up of the Macedonian kingdom, the subjugation of many of the Latin States and cities by the Romans, the first Carthaginian war, and the second Carthaginian war, up to and including the capture of Syracuse.

The records of the progress made in the acquisition of knowledge during those momentous times are necessarily incomplete, but, as far as written records go, they are to be found chiefly in the works of Plato, Aristotle, Theophrastus, Euclid, Eratosthenes, and Archimedes, who lived during those times, and in the writings of Plutarch, Pappus, Arrian, and Athenæus, who lived in later times. There are also the ruins of some of the engineering works constructed wholly or in part during the period under discussion, such as, for example *Via Appia* and *Anio vetus*, the former one of the most important Roman highways and the latter one of Rome's great aqueducts. It is proposed in this paper to consider the chief written records supplemented by information obtained from the remains of some of the engineering works of the period. The records written by men of the period will be from the works of Aristotle and Archimedes, for Plato's works which relate mainly to moral and political philosophy, those of Theophrastus relating mainly

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to botany and mineralogy, the pure mathematics and mathematical geography of Eratosthenes, and the pure geometry and optics of Euclid are of little interest in relation to mechanics and engineering.

Aristotle's researches were chiefly in subjects other than mechanics and engineering, and the genuine works of that great philosopher and zoologist contain but little relating to mechanics and nothing of value about engineering. The so-called Aristotelian treatises include some works dealing with mechanical problems, but these works were written by Aristotle's pupils and followers. It may be mentioned here that want of care in distinguishing Aristotle's own works from the rest of the Aristotelian treatises has often led to errors by attributing to Aristotle statements not to be found in his own works.

The most important passage in Aristotle's works relating to mechanical problems is that on the motion of falling bodies. In his Physics, p. 215, he says that, when bodies fall through different media, the rate of falling depends on the nature of the media, and the weights of the falling bodies, other conditions being the same. His reasoning is sometimes obscure and inconsistent, but evidently he believed that the velocity of a body falling in a given medium was proportional to the weight of the body. This view, long known to be erroneous, was held by Aristotelians until comparatively modern times. The views of the Aristotelians on the motion of falling bodies were those specially selected by Galileo for adverse criticism. The circumstances of the contest between the Aristotelians and Galileo are well-known—their culmination in the experiment of dropping two shot, one ten times heavier than the other, from the top of the leaning tower of Pisa, the persistence of the Aristotelians in their erroneous belief, and the retirement in 1591 of Galileo from his professorship at Pisa. Beyond the above-mentioned discussion of the motion of falling bodies in his Physics there is but little in Aristotle's writings of interest in connection with mechanics.

It is not a reflection on the genius of Aristotle to say that, in his treatment of mechanical problems, he was inferior to Archimedes. The reputation of the latter is due to his work in connection with mechanics and engineering, while that of the former is due to his work in mental, moral and political philosophy, zoology, physics, and meteorology. By the average educated man, Archimedes is associated with the use of powerful levers, or with a means for determining specific densities, or with an appliance for raising water. Archimedes was well-acquainted, however, with the use of compound pulleys and with the worm and wheel; in addition, he worked out some mathematical problems which are of fundamental importance to engineers of to-day.

Many fabulous stories are told about the great ingenuity displayed by Archimedes in designing and constructing weapons for use in war. It would be out of

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place to discuss these stories here. This, however, seems to be true that, during the siege of Syracuse by the Romans under Marcellus, one of Rome's greatest generals, the resistance of the defenders was greatly strengthened by the resources furnished by Archimedes. Among other appliances, he seems to have designed grappling-apparatus which seized the foremost Roman vessels and pulled them towards the walls of Syracuse; this was probably effected by powerful pulley tackle or by worm and wheel apparatus. According to Plutarch and Athenaeus, apparatus of this kind was used by him to show Hieron of Syracuse how a heavily-freighted ship could be moved over dry land.

Archimedes investigated the mechanical properties of levers, and, in his work on the *Equilibrium of Planes,* proved that a lever being at rest under the action of weights and the weight of the lever itself being neglected, the weights are inversely proportional to their distances from the fulcrum. His well-known assertion that if he had a place to stand on he could move the earth is popularly associated with the use of a powerful lever; but Archimedes seems to have contemplated the use of compound pulleys for the purpose. A well-known contrivance invented by him for irrigation purposes, probably when he was in Egypt, is the Archimedean screw or pump.

To him is due the solution of a very important hydrostatic problem, for in his work on *Floating Bodies* he shows that when a solid lighter than a fluid is placed in the fluid and allowed to come to rest the weight of the fluid displaced is equal to that of the solid.

He also determined the position of the centre of gravity of a parallelogram, triangle, and parabolic segment, proved that the area of a sphere is four times that of one of its great circles, that the volume of a sphere is two-thirds of the volume of the circumscribing cylinder, and that the ratio of the circumference of a circle to its diameter is less than 3 1-7 and greater than 3 10-71.

It will be conceded that these achievements entitle Archimedes to be considered one of the greatest pioneers in the acquisition of knowledge, and it is not surprising that to-day the citizens of Syracuse very jealously guard his honour.

Having considered Aristotle and Archimedes in so far as they deal with mechanical problems, we will pass on to consider some of the important engineering works constructed in part at least during the period under discussion.

First may be mentioned the two aqueducts, *Aqua Appia* and *Anio Vetus,* serving to convey water into the Roman city. The construction of the Appian aqueduct was commenced in B.C. 312 by Appius Claudius Cæcus. It was rather more than 10 miles long, and, except for about 300ft. of its length in the city, was underground and generally at a great depth. The Anio aqueduct was begun in 272 B.C. and conveyed water from the Anio into Rome. Its length was about

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43 miles, all underground except for a length of less than a quarter of a mile. Extensive stretches of this aqueduct still remain. It was built of blocks of a volcanic stone called peperino, and its water-course was lined with a thick layer of cement.

As road-makers, bridge-builders, and constructors of fortifications, the Romans were highly efficient. One of the best-known and best-laid roads, *Via Appia,* was begun in 312 B.C. by the Censor Appius Claudius Cæcus. It extended at first from the Capena Gate at Rome to Capua, a distance of about 132 miles; at a much later time it extended to Brundisium. The original road was probably only a gravelled way, but in 298 B.C. a footpath of squared stone (*saxum quadratum*) was laid for a distance of about a mile from the Capena Gate. Later, the whole road as far as Bovillæ, about 12 miles from Rome, was laid with flint; then, during a long period, the road was so much improved and extended that it excelled in grandeur and workmanlike finish. Statius called it the Queen of Highways (*longarum regina viarum*).

Another long and important road, Via Flaminia, was begun in 220 B.C. Leaving Rome on its northern side, this road finally extended northwards to Ariminum on the Adriatic and about nine miles south of the Rubicon.

There does not seem to be any record of any permanent bridge of importance constructed during the period. At Rome, at any rate, the old pile-bridge, *Pons Sublicius,* constructed of some kind of hard wood, probably oak, its parts being held together without the aid of iron nails or fastenings, was the only bridge existing during the period.

Some great engineering works were carried out during the campaigns of Alexander in Asia Minor and Persia, but probably his engineers were most severely tested during the Siege of Tyre. This siege extended over a period of seven months in the year 332 B.C. Alexander was in possession of Old Tyre on the mainland, while New Tyre, the object of his attacks, was on an island facing Old Tyre and situated so as to be almost impregnable. His engineers placed battering rams and other weapons of attack on ships of war and also began the construction of a mole, 200 feet wide, extending in a direction, roughly speaking, of the shortest distance between Old and New Tyre. When the end of the mole was sufficiently near New Tyre, wooden towers protected by hides were erected on it, and were intended to carry offensive weapons, especially battering-rams. The difficulties, however, were great, for the end of the mole near New Tyre had to be laid in very deep water and the Tyrians repeatedly attacked the mole, its workmen and its defenders. By repeated attacks, especially with the aid of ships carrying inflammable material which was ignited, the efforts of Alexander's engineers were greatly paralysed, and finally the damage done by the strong sea

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currents acting at right-angles to the mole was completed by the action of a storm which swept away most of the structure of wood and stone, of which the mole was constructed.

Alexander and his engineers had to decide between abandonment of the idea of constructing a mole or making a new and greater effort. Very soon after the destruction of the mole, a second mole was commenced; this was wider than the first and extended in a south-westerly direction from a convenient part of Old Tyre in order to reduce the effects of the sea currents. Blocks of stone from Old Tyre were built into the new mole together with large trees with their branches from Lebanon. This mole was more successfully completed, and towers carrying powerful battering-rams were erected on it. The effective breach of the Tyrian walls was made, however, by battering-rams carried by some of Alexander's ships.

A great engineering work, some benefits of which are enjoyed to this day, was the laying-out and building of the city of Alexandria by Alexander's engineers and those of his successors. The city was planned on bold lines. Roughly speaking, it was a rectangle, four miles long and one mile wide, with its length extending along the Mediterranean shore. Two streets, about 200 feet wide, bisected the city along its length and breadth respectively, and the rest of the streets extended parallel to one or other of these main streets, thus dividing the city into a large number of rectangles.

Opposite Alexandria, and about a mile distant, is the dazzling white rocky island called Pharos. After Alexander's death and during the reign of Ptolemy Soter the celebrated lighthouse, included among the so-called Seven Wonders of the World, was erected by Sostratus of Cnidus on the eastern end of the island. The lighthouse was built in several storeys, and is said to have been 400 feet high. The island was connected to Alexandria by the Great Mole or Heptastadium, having two gaps to allow free flow of water through the mole and prevent accumulation of mud. These gaps were covered by bridges which could be raised and lowered at will.

Mention has been made of the laying out and building of the city of Alexandria, and, if space permitted, it would be possible to give some information about the engineering works carried out in founding other cities and establishing ports primarily intended for facilitating Alexander's warlike operations. Similarly, during the second Carthaginian War, the Romans established or greatly improved several towns and ports. Puteoli was one of these. By order of the Roman Senate, the old town and harbour were greatly improved; its harbour was enlarged and docks, including dry docks for use in repairing the Roman ships, were constructed, while Puteoli itself was enlarged, fortified, and strongly garrisoned.

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In consequence of these improvements, Puteoli became a great asset to the Romans, whose territory was more than once in danger of complete subjection during that very disastrous war.

It will, perhaps, not be out of place to give an account of two great works which, though primarily works of art, required in their construction all the skill of engineers as well as of architects and sculptors. Both works are included among the Seven Wonders of the World, one being the Temple of Diana at Ephesus and the other the Mausoleum erected by Queen Artemisia at Halicarnassus soon after the year 353 B.C.

The Temple of Diana was commenced in Alexander's time and completed many years later. It was the largest and, in many respects, the most magnificent of all the Greek temples. Built on the site of preceding temples of the goddess in a damp, marshy situation, its foundations were laid on a thick bed of well-rammed charcoal and wool. Its length was 425 feet and width 220 feet; along each side were two rows of 21 Ionic columns each and at each end three rows of 10 columns each; these elegant columns were 60 feet high and, together with the main walls, supported a massive roof.

The Mausoleum seems to have had a stepped base covering a rectangular area about 120 feet long and 90 feet wide. This base supported a massive rectangular chamber, on the top of which were mounted a large number of Ionic columns each nearly 30 feet high. These columns supported a pyramidal structure surmounted by a stone chariot yoked to two massive stone figures of horses and carrying full-sized figures of Artemisia and her consort Mausolus. The total height of the Mausoleum was about 140 feet. This is intended to be only a fair general description of the Mausoleum, for the various reproductions effected by archæologists do not agree in their details.

The works which have been described above are of the kind which, according to modern classification of professions and trades, would fall mainly to the civil engineer, and to the architect, sculptor, mason, and carpenter. They do not represent the work of everyday life; they are some of the show pieces of the ancient world. A question which at once arises in our minds when we consider such works is that of the tools and machines used in the various operations of cutting and working the wood, stone, and other materials employed, and also the means used in hauling and lifting. There must have been elaborate arrangements of hauling and lifting means, such as, for example, winches, rollers travelling over the ground or on inclined timbers, and arrangements of pulleys supported by substantial scaffolding.

For connecting the various structures together, nails and wooden wedges were used for wooden structures, while for securing metal structures in stone the

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use of molten lead was probably known to the Greeks and Romans. The use of screws and screw-bolts was probably unknown. Such well-known tools as hammers, mallets, chisels, axes, and wedges were commonly used. The constantly-recurring operations of forming piles and other balks as well as planks was done by the early method of splitting by means of wedges and finishing to size with chisels or axes, or hand-saws and frame-saws were employed. In the latter part of the period planes of simple form appear to have been used.

There are also the important operations of forming holes in wood and in stone. For wood, gimlets with spherical or at least rounded handles were in use; it is doubtful whether any of these ancient gimlets had a screw point; the use of a threaded or twisted stem was certainly not known until comparatively modern times. With respect to the means used in forming holes in stone, I can only conjecture; probably the operation was performed by means of a chisel and mallet.

This highly interesting subject, that of the tools and machines used in carrying out the works described, deserves far more consideration than I have been able to give it. Probably the tools and machines used were more varied in character and more efficient than we shall over know. The written records and the information derived from remains of tools dug up from the ancient sites of works of the period fail to give us anything like full information. What we know of the works of the period under discussion and of works of even earlier times, the splendid works of art at Athens in the time of Pericles, the great engineering works and works of art at Babylon in the time of Queen Nitocris, the Pyramids and temples of Egypt and the great works of the Carthaginians, the Phoenicians, and the Lydians, may well cause us to desire to know more about the tools and machines used in their construction.

Discussion.

The author said he would, with members' permission, talk about his paper rather than read it, as copies were in their hands; he would, therefore, refer them to it. Originally, he stated, the paper was to have been on Aristotle only, but he found this field too limited; a great deal of time could be spent in, for example, trying to ascertain the precise meaning of Aristotle's statements, but his audience would not be interested in discussing variations in the many editions of Aristotle's treatises. He had, therefore, chosen a period of about 200 years of great mental activity and material progress, embracing the times of Aristotle and Archimedes. The latter was one of the world's great engineers, but a great deal of fable had grown up round him. The pulley was known before the time of Archimedes, but he was the first to elaborate pulley tackle and the worm wheel. To illustrate his

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remarks on roads, the author passed round a sketch map of the Appian and the Flaminian Ways. Other parts of the paper were illustrated by means of a sketch of Old and New Tyre and a plan of Alexandria.

The President thanked the Author for his excellent paper, and called on Col. F. W. Foster to move a vote of thanks. In doing so, the latter enquired how large areas such as temples were roofed in. Mr. C. F. Dendy Marshall, who seconded, said he was still in doubt as to how the ancients lifted such heavy weights as they did; he also enquired if it was probable that the straightness of Roman roads was due to their wheeled carriages having both axles fixed. The vote of thanks was carried unanimously.

Sir George Greenhill referred to the passage in Aristotle's *Physics* and another one in *De Coelo* on falling bodies, and said he thought Aristotle was discussing the terminal velocity, and therefore Galileo was demolishing a theory set up, not by Aristotle but by Aristotelians. Sir George also referred to Galileo's observation on the swinging lamp in Pisa Cathedral.

The Secretary enquired if the great mental activity of the period under review could be explained. He also asked if there was any hint that any works of Archimedes had been lost.

Mr. G. F. Zimmer said that he had spent much time in trying to ascertain whether Archimedes invented the screw that goes by his name. It was certainly not used in ancient Egypt, and he was doubtful as to the attribution. Did the Egyptians not use diamond or sand with water for boring holes in syenite, etc.?

Mr. E. Lancaster Burne thought that the bronze tools of the time were inadequate to have done what remains to us.

Mr. Chope said that, as Galileo's name had been brought in, he might be excused for stating that a model of his pendulum clock had been presented to the Clockmakers' Company Collection at the Guildhall. Had the statement in old writers that wool was used for the foundations of temples, etc., any confirmation?

Mr. H. G. Graves said that drilling holes with sand was done in neolithic times. He had seen in India weights of, say, 12 tons lifted as much as 40 feet from the ground by underfilling with earth.

Mr. Legros said that too much was made of the difficulty of moving and lifting heavy weights. He instanced a case where a heavy safe was got into a recess little larger than itself without lifting tackle, but with merely a piece of gas barrel. He thought some information would be got by photographing tool marks on the stones of ancient structures.

The Author, in reply, said that satisfactory answers to some of the questions asked would require careful consideration and more knowledge of the subjects referred to than he possessed. The question relating to roofs had been much dis-

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cussed, and would take too long to go into. Generally speaking, temples and amphitheatres of large area did not have roofs, and where roofs were used it is probable that large wooden beams were used. The arch originated in the East, not the West, and the genuine keystone arch was of comparatively late date. The Cloaca Maxima at Rome attributed to Ancus Martius was arched, but it is now admitted that it was built, not by that king, but by a Censor of that name in the later period of the Republic. Roman roads, which were usually military roads, were straight as a matter of principle, not because of the carriages to be used on them. He could not agree altogether with Sir George. Aristotle had the nature of the medium in his mind, but made no mention of terminal velocity. He may have intended his words to have a special meaning, but he does not say so. The Aristotelians were more dogmatic than their Master, and Galileo, who opposed their uncompromising opinions, was a better follower of Aristotle than they were. As to lifting heavy weights, he could only offer the old explanation, viz., inclined planes and rollers. As to the Archimedean screw, one had to be satisfied with tradition, which ascribed the screw to Archimedes. For boring holes in stone and for sawing it, sand was used in early times, without doubt. As to the mental activity of the period, he would explain it by attributing it to Greek influence. Many of the surrounding peoples, like the Macedonians, sought to become Hellenized; their kings wished to be considered Greeks, and fostered Greek culture. There was no passage known to the author to suggest that any books of Archimedes had been lost. In reply to Mr. Chope, the author said that the use of wool in foundations appeared to be strange, but wool and charcoal were materials mentioned in the old authors.

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Timothy Hackworth and the Locomotive.

By Robert Young.[1]

(*Read at Caxton Hall, Westminster, March 1st, 1922.*)

For the present purpose, which is to put before you as full an account of the locomotive achievements and personality of Timothy Hackworth as the time at my disposal permits, I propose beginning with the year 1824. I would preface, this, however, by stating that Hackworth's locomotive experience dated from 1811, as from that year till 1816 he was building and supervising the locomotives at Wylam Colliery. From Wylam he went to Walbottle, where he remained until 1824, when, at the age of twenty-eight, he resumed his activities in that sphere of labour which became his life-work. In that year Stephenson's various activities had assumed important dimensions. In addition to the engine works, he was constructing the Stockton and Darlington Railway, and had also been appointed surveyor of the Liverpool and Manchester Railway, where his presence for some months became imperative. He applied to Hackworth, who agreed to go to manage the locomotive works at Newcastle, purely as a temporary measure—as a borrowed man—during the few months of Stephenson's necessary visit to Liverpool,[2] and at Newcastle part of Hackworth's work was in connection with the building of the first locomotive for the Stockton and Darlington Railway, constructed from George Stephenson's matured designs.

Hackworth remained at the Forth-street works during the agreed period, carrying out his work efficiently, but not materially altering the locomotives under construction. He did, however, suggest dispensing with the chain coupling which had long been a feature of the Stephenson engines, and in place of it fitted side rods on the wheels, the first ever used on a locomotive.[3] When Stephenson returned he was very desirous that Hackworth should join him in the business, going to the length of offering him one-half of his own interest, a proposal which was declined.[4]

Stephenson, unable to secure Hackworth in his own firm, was well aware that he might prove a serious business rival in Newcastle, and strongly urged his

[1]The author is a grandson of Timothy Hackworth, and some of the particulars given are drawn from family knowledge.

[2]*Practical Mechanics' Journal*, "Memoir of Timothy Hackworth," Vol. III., 1850-51, p. 225.

[3]John Hackworth's List of Timothy Hackworth's Inventions.

[4]*Practical Mechanics' Journal*, "Memoir of Timothy Hackworth," Vol. III., 1850-51, p. 225.

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being appointed engineer to the Stockton and Darlington Railway, a position which had previously been suggested to Hackworth, which, when definitely made, he accepted. He entered on his duties in June, 1825, and for the next fifteen years, through the most critical period to one of great success, maintained his connection with that railway.

There is a popular conception that the early days of this railway were marked by successful operation, and that the locomotive at once solved all difficulties of transport and entered on an uninterrupted course of triumph. The exact opposite was the case. The first two years were a period of anxiety and disappointment, almost of despair. The locomotives failed the Company. There is no desire on my part to depreciate them. They were of the latest approved type. Hackworth himself had assisted in their design and construction, and his fortunes were closely bound up in their success. But the facts are clear, and the results of their working produced a state of affairs approaching panic. The late Joseph Tomlinson in his presidential address to the Institution of Mechanical Engineers in 1890 said: "When first Locomotion was put to work it would not make steam, and the fire tube had to be taken out and replaced by a return tube."[5] In his "Outline History of the Locomotive Engine," the late Theodore West tells us that in awkward and slippery weather the speed would flag rapidly, and driver and fireman would prise the engine wheels with crowbars till weary, when they would stop, fire up, and then sit down on the bank for a quiet pipe till steam had again risen.[6] An old workman who helped to light up Locomotion for its first trip said, "Eight waggons was as many as she could trail."[7] In *The Engineer*, John W. Hackworth wrote that with sixteen chaldron wagons these engines required fourteen and often fifteen hours to run from New Shildon to Stockton—20 miles and back.[8] These circumstances were, of course, known to the Railway Committee, though discreetly omitted from the reports to the shareholders. Edward Pease wrote to Robert Stephenson in April, 1826, after the third locomotive, Black Diamond, had been delivered to the railway, saying that the business in Newcastle had suffered very much from his absence, and that unless he soon return it will be given up as "What is done is not done with credit to the house."[9] In 1827 Robert Stephenson received a similar letter from Thomas Richardson."[10]

The situation was not a very cheerful one. The capital was all spent. The loans and debts owing amounted to more than £100,000. Some of the branch lines forming part of the original scheme was not even begun, and there was a

[5]Proceedings, Institution of Mechanical Engineers, May, 1890, p. 182.
[6]Proceedings, Cleveland Institution of Engineers, March, 1886, p. 14.
[7]The Diaries of Edward Pease, p. 380.
[8]*The Engineer*, August 14th, 1857.
[9]Smiles' "Lives of Geo. and Robert Stephenson," 1862, p. 250.
[10]Jeaffreson's "Life of Robert Stephenson," 1864, I., p. 101.

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shortage of money to pay current expenses.[11] Some of those who had advanced money were demanding it back, and an attempt to raise a new loan failed. During the ensuing months additional horses were employed on the line, and there was every prospect that the much-vaunted "travelling engine," uncertain, irregular, and constantly under overhaul, would make a final departure. "Owing to the inefficient condition of the locomotive power," says the *Practical Mechanics' Journal,* "the company had all but determined to abandon steam in favour of horses, when Mr. Hackworth proposed to construct an engine suitable for working the traffic.[12] The offer was accepted, and thus the Royal George came into existence. As a necessary economy, the boiler of a locomotive, built by Robert Wilson, of Newcastle, was taken for the new engine, lengthened and enlarged in diameter. The single straight flue was replaced by a malleable iron return flue, and this was the first boiler on the Stockton and Darlington Railway in which a return flue was fitted as part of the original structure, the former engines being all delivered with the straight flue boiler to which Stephenson adhered for so many years.

The boiler as rebuilt was 13ft. long by 4ft. 4in. diameter. The internal horseshoe flue was 26in. diameter at the furnace end, 18in. at the chimney end, and the heating surface was thus increased from some 60 square feet to 141 square feet. The cylinders were 11in. diameter, stroke 20in. They were placed vertically at the back of the engine working downwards and directly to cranks on the trailing pair of wheels, the pistons being guided by parallel motion, working a valve shaft on which were two loose excentrics. The wheels were Hackworth's "plug" wheels, 4ft. diameter, and four of the wheels were spring-mounted, being the first instance of a locomotive being carried on bearing springs. The springs were longitudinal, hinged on the main frame and acted also as balance beams. The Royal George had also a malleable iron cistern in which the feed water was heated by a portion of the exhaust steam, while another portion could be used if required as a jet under the grate to aid combustion. These were operated by a cock at the will of the driver. But the most important feature was the arrangement of the exhaust pipe as a perfect blast. Hitherto the Stockton and Darlington engines had been provided with two exhaust pipes, one from each cylinder, which were carried through the chimney and discharged the waste steam upwards just inside the chimney.[13] Hackworth brought his single pipe direct into the centre of the chimney, where it was bent upwards with a coned malleable nozzle, through which the steam was ejected with greatly increased force, forming a powerful blast, perfect in its application and enabling

[11] "The North-Eastern Railway," by W. W. Tomlinson, p. 138.
[12] *Practical Mechanics' Journal*, June, 1850.
[13] J. W. Hackworth in *The Engineer*, August 14th, 1857.

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boiler pressure to be maintained under all conditions. Into the vexed question of the invention of the blast-pipe I do not propose to enter, as the full consideration of this subject would occupy a whole evening. I will content myself therefore by saying that I believe the arrangement of the exhaust pipes in the Royal George provided the most complete and efficient blast produced up to the year 1827.

The engine was tried in September, 1827, began running regular traffic in November of the same year, and immediately proved its capabilities. In an old memorandum book of Timothy Hackworth's, I find the following notes: "William Golding Royal George engine on the evening of 13 Dec. 1827 coming up the line with 20 waggons the ring round the fire tube gave way two feet in length, he put the waggons into the siding. This engine was put on the line a fortnight before, made a journey each day, one journey to Darlington with 24 waggons and can gender steam to propel the waggons well. Set off with the first journey to Stockton with the said engine Nov. 29, 1827, performed the journey well." This unfortunate accident laid the engine up for five weeks, but under date January 22nd, 1828, is the further note: "Royal George Locomotive made two Darlington journeys, Golding engine tender." Its career was then one of great success, and it may reasonably be said that on the results of its working the future of the locomotive system depended so far as the Stockton and Darlington Railway was concerned, and that its failure would seriously, if not fatally, have affected the introduction of steam locomotives elsewhere. During 1828 it conveyed 22,422 tons of coal over 20 miles at a rate of a farthing a ton per mile. The cost of this, including repairs, maintenance and interest on capital was £466, where, according to the *Practical Mechanics' Journal,* horses for the same work cost £998.[14]

The success of the Royal George must be considered in relation to the work demanded of it, and for which it was designed, namely, the coal traffic. Speed on the single railway, with its mixed traffic, was neither desirable nor practicable. The Committee discouraged it and severely punished offenders. While the new engine could travel 11 miles per hour with its load, speed was at this period limited to 5 miles. Its regular train load was twenty-four wagons, each with a deadweight of 1 ton 4 cwt., and each carrying from 53 cwt to 3 tons of coal,[15] nearly 100 tons gross without tenders. Several small circumstances confirm the evidence of efficiency of the engine, which are not devoid of interest. The Committee—always rigidly economical and far more prone to inflict fines than bestow rewards—actually voted the sum of £20 to Hackworth as a bonus for building the Royal George.[16] The driver, William Gowland, earned considerably more wages

[14] *Practical Mechanics' Journal*, June, 1850.

[15] Timothy Hackworth to Robert Stephenson. Draft of original letter in the writer's possession.

[16] "The North-Eastern Railway," by W. W. Tomlinson, p. 144.

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than any of the others,[17] the pay being on tonnage rate and, therefore, an accurate gauge of work done. Timothy Hackworth's memorandum book for part of 1828 gives the wages earned by the five drivers in March of that year, which form a very good testimonial to the new engine. The list is as under: James Stephenson received £18 5s. 4d.; Robert Morrow received £18 9s. 4d.; William Gowland received £37 18s. 11d.; Michael Law received £22 18s. 1d.; John Cree received £22 5s. 5d.

It can scarcely be considered surprising that, as Gowland wrote in *The Engineer*, he was "an envied man,"[18] and that Morrow, to whom the Royal George had first been offered, regretted his refusal.

After the Royal George had been running for a year, the Committee passed the following resolution: "From an accurate observation of the locomotive with six wheels and springs, the Committee have every reason to be satisfied the same is a great improvement. It is resolved that T. H. be directed to attend to having similar improvement made in all our engines as early as possible."[19] So far as financial results followed the introduction of the new engine, the balance sheet of the company for the year ending June 30th, 1828, when the Royal George had been running seven months only, shows the coals conveyed had increased by 50 per cent. and the receipts were up £5,000, the ratio of working expenses being reduced from 64 per cent. to 52 per cent.[20]

It must be borne in mind that the directors of the Liverpool and Manchester Railway appointed a deputation to report as to the feasibility of stationary or travelling engines for their railway, and this report, published in March, 1829, recommended the use of stationary engines. Robert Stephenson thereupon led a powerful opposition to it, in which he enlisted Hackworth's assistance, and it is a very significant fact that he had induced the deputation to insert in their report an account of the work done by the Royal George. Not one of his own locomotives, not the Experiment at Shildon, not the Lancashire Witch at Bolton, nor the Twin Sisters at Liverpool, but Hackworth's engine. Of this engine the report said:—

"Hackworth's engine is undoubtedly the most powerful that has yet been made, as the amount of tons conveyed by it, compared with other engines, proves. Its consumption of coal per ton of goods conveyed one mile, at the rate of 11 miles per hour, was 1.60 lb.; Blenkinsop's engine, at 4 miles per hour, 2.75 lb.; Killingworth and Hetton engines, at 4 miles per hour, 2.25 lb.[21]

I have dealt at some length on the Royal George, because it marked a new

[17] *Ibid.*, p. 151.
[18] *The Engineer*, October 23rd, 1857.
[19] Minutes of Sub-committee, October 31st, 1828.
[20] "The North-Eastern Railway," p. 136.
[21] "Reports to the Liverpool and Manchester Railway Directors," by James Walker and J. U. Rastrick, p. 17.

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era in locomotive building and definitely asserted the superiority of steam over horse traction. So long as the railway subordinated speed to power, or were content without the combination of speed and power, this type of locomotive was worked with great success and economy. It was cheap to build, to run and to maintain. It was simple, strong and durable, and the type held its own for many years. Similar engines were introduced on other coal railways and some were still at work in 1882.

It seems to me that for his work alone in producing this engine—at a specially critical period in locomotive history—Hackworth's name deserves to be included in the front rank of the great locomotive pioneers.

The next engine built by Hackworth was the Victory, in 1829, on similar lines to the Royal George, but the pistons were guided by circular slide bars instead of parallel motion, and the cylinders were 12in. diameter with a stroke of 22in.

In April, 1829, the directors of the Liverpool and Manchester Railway decided to have a locomotive competition which was fixed for October of the same year. Hackworth resolved to compete and built a small engine which he called the Sanspareil, similar in design to the Royal George, but on four wheels only. This competition has passed into history. It was won by Robert Stephenson's Rocket, but for the first two hours the Sanspareil ran with great regularity, covering over 25 miles, and as a report of the contest says, "It was soon manifest that a very powerful competitor had entered the field."[22] The cause of failure was the bursting of the partition between the bore of one cylinder and the port way along the cylinder side,[23] which happened soon after the start, the fracture opening at every stroke a direct communication from the steam pipe to the chimney. This not only caused great loss of steam, but also the ejection of fuel at each opening of the slide valve, and rendered the Sanspareil's chance hopeless. The cylinder was replaced immediately after the contest, the engine was purchased by the directors, was sent to the Bolton and Leigh Railway, where it ran for many years, and now has its resting place in the Science Museum, South Kensington.

Nicholas Wood's chronicle of the contest—the universally accepted authority—did much injustice to Hackworth. He assigned the fuel ejection to a too powerful blast, and gave the fuel consumption—which was of course excessive—without reference to the unfortunate cause of it.[24] It is only fair to state that the whole work of the Sanspareil could not be carried out in the small repair shop at New Shildon. The boiler was made at Bedlington, and the cylinders—the cause of all

[22] *Arcana of Science and Art*, 1830, p. 11.

[23] See Timothy Hackworth's letter to the directors of the Liverpool and Manchester Railway.

[24] Wood's "Treatise on Railways," third edition, p. 506 *et seq.*

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the trouble—were cast and finished at the factory of Robert Stephenson and Co., Newcastle.

Immediately after his return to Shildon, Hackworth was instructed to design an engine for passenger traffic for the extension of the railway from Stockton to Middlesbrough. This engine marked a new departure. Speed, reliability and steadiness in running were required. The engine was designed in 1829, approved early in 1830, and the plans were sent to Robert Stephenson and Co., by whom the engine was built. Among the novel features were a copper circular steam dome, four coupled wheels, 5ft. diameter, the largest yet made, inside horizontal cylinders with crank axle, and valve motion reversible by a single lever. The cylinders were 9in. diameter by 16in. stroke, placed under the trailing end of the engine. The boiler was also on new lines, a single flue 9ft. 3in. long with radiating small tubes passed transversely through the main flue, and through these water circulated. Ordered at the beginning of March, 1830, it was not finished till December, when it was used to open the new line to Middlesbrough, and known as the Globe, continued in successful use for nine years, when it came to an untimely end through the explosion of the boiler.

In 1833 Hackworth entered into an agreement with the railway company by which he took over the rolling stock at a valuation, found all material and workmen, and contracted for the whole traffic for a payment of four-tenths of a penny per ton of goods per mile, an arrangement which lasted till 1840. He thus obtained full independence of action, and was able to open works of his own at Shildon. During the next seven years he turned out a large number of locomotives. He designed and built the Magnet for the Stockton and Darlington Railway in 1835, and the Enterprise, from the same plans, was built by W. and A. Kitching. These were of the Wilberforce class, but more powerful, while the boilers had 110 boiler tubes. The first engine ever sent to Russia was built by him in 1836. It was a fire-box engine, its chief peculiarity being a long crank and short stroke known as a double trunk engine. An engine very similar was supplied by him to the Stockton and Darlington Railway in 1837, called the Arrow, which ran for many years. Other engines, designed and built by him up to 1840, included the Beehive, the Briton, the Tory, Auckland, Despatch and Dart. The Beehive and Briton had vertical cylinders similar to the Magnet. The Tory, 1838, was the first of a new type, with sloping cylinders bolted on either side of the trailing end of the boiler, and the Middlesbrough, Ocean and Etherley were by William Lister of Darlington were copied from it. The Whig and Tees were also copied from the Tory, and built by the brothers Kitching. Hackworth built four engines for the South Hetton Coal Company, and two for the Clarence Railway. In 1838-39 three were sent to Nova Scotia, the Samson, Hercules and John

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Buddle, the first locomotives in British North America, which ran till 1882, and one of which, the Samson, was under steam at the Chicago Exhibition of 1893.

In 1840 Hackworth ceased his connection with the railway, but continued building locomotives at his Shildon works till his death in 1850. During these later years he built the Coxhoe and the Evenwood for the Clarence Railway, the Leader and the Trader for the Stockton and Darlington Railway in 1842, also locomotives for the Seghill Colliery Company, the John and Samson, and engines for the Earl of Durham's Railway, the Seaton Delaval Colliery the Cramlington Coal Company, the Stanhope and Tyne Railway and the Llanelly Mineral Railway Company. Twelve locomotives for the London and Brighton Railway were built during 1846-48, and his last engine, the Sanspareil No. 2, was completed in 1849, a six-wheel single driver, which, after his death, was purchased by the North-Eastern Railway, on which it ran for many years, being remodelled in 1878.

An engineer's career, merely summed up in the number of locomotives he has built, is necessarily incomplete. And while any claim to distinction put forward on behalf of Hackworth must of necessity depend upon his engineering achievements, his life's work would be incorrectly portrayed if it did not include some account expressed other than as engine output. He was not only a great engineer, but an upright, honourable man, who, while absorbed in his work, yet found time to do a vast deal for others. Till he went to New Shildon, in 1825, the place had no existence. As the township grew, he was the acknowledged head, and held sway there for twenty-five years. He was a kind and sympathetic master, who earned the respect and affection of his men, and among them labour troubles were unknown. Out of the heterogeneous material which made up the population of that early railway village, he raised a class of mechanics whose skill became famous, and an apprenticeship under Timothy Hackworth was at once an education and an assurance of work elsewhere. But he did more than provide work for them. He looked after their religious needs and their recreation.

Hackworth's education was that of the village school, where he remained till he was fourteen, when his seven years' apprenticeship began. He was ever a diligent student, deeply interested in scientific subjects, and became a member of the British Association for the Advancement of Science in its early days. His position at New Shildon brought him into touch with many of the leading men of the day, the entertainment of whom was a great pleasure to him. He had all the hospitality of the North countryman, and delighted to gather round him people in various walks of life, and possessing a considerable fund of information and a strong sense of humour, we may reasonably presume the pleasure was mutual. He found his fullest occupation in the busy if confined area of which his

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home was the centre. In his young days he had been an accomplished dancer, and though the art was not encouraged by his religious friends, he taught all his children. He delighted in music, in which his daughters were carefully trained. Another of his recreations was gardening, to which he devoted such spare time as he was able.

His engineering establishment was called Soho Works, the name being suggested by Joseph Pease, jun., to whom he was greatly attached, and with whom a sincere friendship lasted through life. Both with Joseph Pease, and his younger brother Henry, his relations were always of the happiest kind.

In appearance Hackworth was a tall, handsome man of fine physique, well developed by his early trade as a smith (*see* Pl. XV). He came of a tall race, stood over six feet high, and always maintained an erect figure. His features have been described as those of a poet saint rather than a practical engineer. An old Stockton and Darlington driver said, " He was a fine, tall, majestic man, a real gentleman, who never let a wrong word pass his lips. His appearance," he added, " was such that I think no man ever passed him without a respectful salute." He was never a wealthy man. He had not the money-making instinct, which few men with the inventive faculty possess, and he was of a generous nature, known as an open-hearted and open-handed man. What Hackworth lacked was the spur of personal ambition, a trait which may sometimes be well dispensed with. It would have brought him more prominently before the world, but to his death in 1850, at the age of sixty-four, he remained a humble-minded man, indifferent to public applause, and content that the work he had accomplished should speak for itself.

As for that work with regard to the locomotive, I will close this too hurried review in the words of the late Daniel Kinnear Clark, who wrote, " No single individual in this country had, up till the year 1830, done so much for the improvement of the locomotive and for its establishment as a permanent railway motor as Mr. Timothy Hackworth."[25]

The paper was illustrated by twelve lantern slides of engines built by Hackworth. The author also exhibited some original drawings, portraits, and several autograph letters written to Hackworth by George and Robert Stephenson during the early years of the Stockton and Darlington Railway. A few of these have been reproduced (*see* Plates XV. to XIX.)

LETTERS, DRAWINGS, ETC., EXHIBITED.

A.L. from George Stephenson to Hackworth regarding the locomotives on the Stockton and Darlington Railway, Jan. 12 (1826).

[25] " Railway Machinery," by D. K. Clark, p. 9.

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A.L. from George Stephenson to Hackworth asking how the new engine suits and whether any improvements can be made, and other matters, May 3, 1826.

A.L. from Robert Stephenson to Hackworth about rumours conveyed to the directors of the Liverpool and Manchester Railway, that horses were beating the locomotives off the Stockton and Darlington line, July 7, 1828.

Reproduction of A.L. from George Stephenson to Hackworth asking if it is true the engines are to be laid off, and saying the new engine at Bolton works beautifully. He thinks the blast will answer, " two bellows worked by eccentrics underneath the tender." Also refers to his plan of carrying horses. 25 July, 1828.

A.L. from Robert Stephenson to Hackworth asking for information in order to reply to the reports of Messrs. Rastrick and Walker, who had recommended stationary engines for the Liverpool and Manchester Railway. March 17, 1829.

Original draft of Hackworth's reply to above letter. April 9, 1829. (*See* Pl. XVII.)

A.L. from William Kitching (of the S. & D. Railway Committee) to Hackworth, on the Rainhill Competition and other matters. 17 Oct., 1829.

Original draft of letter from Hackworth to the directors of the Liverpool and Manchester Railway about the Sanspareil, undated, but Oct., 1829.

Photograph of the model of the Royal George, made by Hackworth, in the Science Museum, South Kensington.

Engraving of the Royal George, from the late Joseph Tomlinson's collection. Proc. Inst. Mech. Eng., May, 1890.

Photograph of the full-sized model of the Sanspareil, constructed for and exhibited at the Chicago Exhibition, 1893.

Photograph of the Sanspareil, in the Science Museum, South Kensington.

Original drawings of the Victory (built 1829) of the Planet and of the Globe (built 1830), all on one sheet. 1831. (*See* Pl. XVIII.)

Medal issued when the Stockton and Darlington Railway was extended from Stockton to Middlesbrough, showing on the obverse the coal staithes designed and erected by Hackworth, and on the reverse side the railway suspension bridge over the Tees. Dec., 1830.

Engraving of the Wilberforce Locomotive, 1832, from Joseph Tomlinson's collection.

Timothy Hackworth's business card, showing the Globe engine.

Original water-colour of Hackworth, from life.

Reproduction of S. & D. Railway time table, 1837, with vignette of the locomotive Magnet, built 1835.

Original drawing of locomotive for Russia, 1836. (*See* Pl. XIX.)

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Photograph of the Samson, 1838, first locomotive sent to British N. America, as exhibited at the Chicago Exhibition of 1893.

Engraving of the Middlesbrough, 1838, from Joseph Tomlinson's collection.

Photograph of the Despatch, 1839, from John Graham's notebook.

Photograph of the Dart, 1840, as shown at the Railway Jubilee, 1875.

Engraving of the Leader, 1842, from Joseph Tomlinson's collection.

Drawing of the Sanspareil, 1849—Hackworth's last locomotive. (*See* Pl. XIX.)

Discussion.

Mr. Pendred rose to propose a vote of thanks to the author for his paper which he considered exceptionally valuable, in that it was based on documentary material in the family possession—material that he understood the author had used in writing a Life of Hackworth; he trusted that the work would be published. There was one point he would refer to, and that was the invention of coupling rods. In a book just published on the Life of Isaac Dodds,[1] it was stated that young Dodds suggested coupling rods to George Stephenson in 1815. He would like to know if that statement could be supported.

Mr. Forward, seconding the motion, said members were much indebted to the author for bringing his evidence before them. The author had, quite naturally, given Hackworth full credit for what he had done, but had, in his opinion, been too hard on George Stephenson. In 1827 locomotives were distinctly cheaper than horses, and there was never any intention of abandoning the former. A special test on the Stockton and Darlington Railway of about 4,000 tons hauled, showed a saving of 57 per cent., while the average saving, probably for a whole year or longer, was nearly 30 per cent., as stated in the Directors' Report of July, 1827. As to the earnings of the different locomotives, Tomlinson[2] gives the figures for the whole year, and these were fairer than the single month taken by the author. The "Royal George" could not be said to have been an immediate success. It only worked for two weeks, and was then laid off for five weeks for repairs. He believed that, as built, it had no springs—that was the condition of the original model at South Kensington—and he had recently come across a report by two Prussian engineers[3] who visited England in 1827 that confirmed his view. (Here Mr. Forward read an extract from the report in question.) Concluding, he considered the encomium of D. K. Clark on Hackworth as altogether exaggerated. The vote of thanks was carried by acclamation.

[1] A Story of Railway Pioneers, being an account of the Inventions and Works of Isaac Dodds. Major S. Snell, M.C., late R.E. 1821, 8vo.

[2] History of North-Eastern Railway, p. 151.

[3] E. von Oeynhausen and H. von Decken. *Karstens Archiv für Bergbau und Hüttenwesen*, 1829.

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Major Hurlstone Hardy said the idea of coupling rods must have occurred to many people. The one who applied it, in his opinion, deserved the credit, and that one was Hackworth. Mr. Jenkins said he would like to see a page of the original letters reproduced when the paper appeared in the "Transactions." Mr. Tyas also spoke.

The author, in reply, was glad to be able to state that his book would be published.[4] The statement as to the application of side rods was made on the authority of Hackworth's son, J. W. Hackworth, and had not hitherto been challenged, but he would look into the work referred to by Mr. Pendred.

As to the relative cost of locomotives and horses on the railway, he was satisfied that there was a period of great uncertainty and doubt. Figures on the subject given by Tomlinson in the work already referred to seemed to him to be quite at variance. Two versions of the costs were given on the same page (p. 142) referring to the same period, but differing somewhat from each other.

The statement as to bearing springs on the "Royal George" was again based on a statement by J. W. Hackworth, but the evidence of the Prussian engineers, unearthed by Mr. Forward, was of extraordinary interest. If he were, on examination, satisfied with it, he would modify or withdraw his statement.

Correspondence.

Mr. J. G. H. Warren wrote that he much regretted he was unable to be present at the reading of Mr. Young's paper, as he should have liked to have offered criticisms upon many of the statements made therein. In his opinion, the author had relied too much on the writings of the late J. W. Hackworth, who, in trying to bring into relief the work and character of his father, thought it necessary to discredit the Stephensons.

From considerations of space the writer confined his observations to the following statements of the author:—

(a) "Stephenson, unable to secure Hackworth in his own firm, was well aware that he might prove a serious business rival in Newcastle, and strongly urged his being appointed engineer to the Stockton and Darlington Railway."

Such behaviour on Stephenson's part is inconsistent with what is recorded of his character. For example, he is known to have recommended malleable iron rails for the Stockton and Darlington Railway, instead of the cast iron rails in which he had a direct pecuniary interest. In reference to this action there is a striking testimony to Stephenson's character in a letter written by Michael Longridge to Edward Pease, now to be seen in the railway collection in the Newcastle

[4]This has now taken place. *See* "Timothy Hackworth and the Locomotive," 1923.

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Library. There is other contemporary testimony to a similar effect. Surely it is enough to state that Stephenson, who was no mean judge of ability in others, was sufficiently convinced of Hackworth's capabilities, as to recommend him for the appointment on his merits as an engineer, and not on his potentialities as a rival.

(b) "The first two years were a period of anxiety and disappointment, almost of despair. The locomotives failed the company."

The first part of the statement may be admitted; the second is too sweeping, if not altogether incorrect. The success of the first engine and "the admirable manner in which it does all and more than all that was expected of it" is recorded in the *Gentleman's Magazine* of December, 1825. It is true that the directors had serious cause to complain of the workmanship of the second engine, and they recorded their dissatisfaction with the builders in no uncertain terms. But this is far from saying that the locomotive had "definitely failed the company."

(c) "Owing to the inefficient condition of the locomotive power, the company had all but determined to abandon steam in favour of horses, when Mr. Hackworth proposed to construct an engine suitable for working the traffic."

This is J. W. Hackworth's statement, and the engine referred to is the "Royal George."

It is true that, during the year 1826 and the early part of 1827, the question of the relative cost of traction by locomotives and horses was under consideration and that opinion was still divided, but the question was settled before July, 1827, *i.e.*, four months before the "Royal George," according to the author's own statement, began running regular traffic, as will be gathered from the following extract from a printed report of the directors to the shareholders, dated July, 1827, and to be seen in the Darlington Library: "It may be satisfactory to the general meeting to be informed, as a result of the strict scrutiny into the subject, that there appears to be a saving of nearly 30 per cent. in favour of haulage performed by locomotive engines, when compared with its being done by horses."

Further evidence to the same effect will be found in Tomlinson, "History of the North Eastern Railway."

(d) "It must be borne in mind that the directors of the Liverpool and Manchester Railway appointed a deputation to report as to the feasibility of stationary or travelling engines for their railway, and this report, published in March, 1829, recommended the use of stationary engines. Robert Stephenson thereupon led a powerful opposition to it, in which he enlisted Hackworth's assistance, and it is a very significant fact that he had induced the deputation to insert in their report an account of the work done by the 'Royal George.'

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Not one of his own locomotives, not the 'Experiment' at Shildon, nor the 'Lancashire Witch' at Bolton, nor the 'Twin Sisters' at Liverpool, but Hackworth's engine."

This statement, based presumably upon the fact that Robert Stephenson wrote to Hackworth on March 17th, 1829, for particulars of the performance of the "Royal George," is so misleading as to be incorrect.

In their "Reply to the Report of Mr. James Walker to the Directors of the Liverpool and Manchester Railway" (*i.e.*, the report in question, published 1829), Robert Stephenson and Joseph Locke made the following comment on Walker's conclusions as to the power of the Darlington engines, and on his remarks and calculations based on a performance of the "Lancashire Witch" on the Bolton and Leigh Railway: "The Lancashire Witch was the most efficient (*i.e.*, locomotive) Mr. Walker had examined, and deductions from its performance would have approximated nearer to the truth than data drawn from the Darlington engines that have been several years in use working under great disadvantages."

Walker's own figures show that the "Lancashire Witch" was exceptionally efficient, so much so apparently that Walker ruled it out as too exceptional to be taken as a basis for calculation!

Further, in comparing the work done by the "Royal George" with the earlier engines on the Stockton and Darlington Railway, it appears from Walker's own table that the loads hauled are in almost direct proportion to the weight of the engine in each case. In other words, the "Royal George" was just so much more powerful as it was heavier than its predecessors.

The "Lancashire Witch" was a much lighter locomotive than the "Royal George," but in the writer's opinion, in some ways, marked a greater step forward in design than the "Royal George," for example, in the arrangement of its cylinders and driving gear, which led on to the "Rocket"; we may echo Robert Stephenson's remark that the "Lancashire Witch" has not received, at the hands of historians, the notice it deserves.

(e) "The cylinders (*i.e.*, of the Sanspareil)—the cause of all the trouble—were cast and finished at the factory of Robert Stephenson and Co., Newcastle."

If the author means to infer that the defective cylinders were the cause of the rejection of the "Sanspareil," this is an unfair deduction. The author omits to mention that the engine did not conform, in the matter of weight and certain other features, to the stipulated requirements of the directors. Evidence on these points is available.

Mr. Young wrote in reply: In his allusions to the late John Hackworth, I think Mr. Warren makes a mistake. So far as I know, John Hackworth did not

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"discredit the Stephensons." What he did do was to combat with great vigour many assertions of Nicholas Wood, Samuel Smiles, and other writers on locomotive history.

I am personally interested because John Hackworth was my uncle. I knew him intimately in my early days as an upright (and downright) man, whose rough exterior covered a tender and generous nature, who was careful as to the correctness of his statements, and no less emphatic in the expression of them. He called a spade a spade, but not a wheelbarrow as many of his opponents did. He belonged to the early railway period. His knowledge was first hand; as the son of his father, and brought up in the centre of locomotive development, the impartial student of railway history cannot afford to ignore him. His evidence must be given the same consideration as is given to others of the time, weighed impartially, and treated with equal respect. "If any living man," he wrote of the Stockton and Darlington Railway, "knows anything of its history and working operations, I am the man—yea, to the minutiæ."

What he said he repeated, not once but scores of times. He wrote, spoke, and lectured over a period of many years. Much that he said was questioned, but no important declaration by him was ever disproved. It is unjust airily to waive aside his remarks as partial and unreliable, and at the same time implicitly to accept the secondhand knowledge of others.

But, curiously enough, the comments of Mr. Warren may be replied to without special reference to John Hackworth. The first complaint is that I dealt unfairly with George Stephenson over the matter of Timothy Hackworth's appointment as engineer of the Stockton and Darlington Railway. If I did an injustice to Stephenson's character, I regret it, but it appears to me fair comment. Stephenson had started his factory with small capital, and was working at a loss. If Hackworth had started next door to him such action could not fail to have had a damaging effect on Stephenson's business, and the arrangement made by which Hackworth was to go to the Railway—of necessity giving up his Newcastle scheme—was not discreditable to either, nor inconsistent with honourable procedure.

Mr. Warren's next objection is to the statement that the first Stockton & Darlington locomotives failed the Company. We appear to differ as to what constitutes failure, and what success. I briefly summarise the reasons already given. Four Stephenson engines were supplied during 1825-26, all alike, and of the Killingworth and Hetton type, such as Stephenson had built two years before under his patent. In December, 1824, discussing their partnership agreement, Stephenson tells Edward Pease that he does not see he can make any additions to his engine that would entitle him to sue for a new patent. Later, three of his engines are dispensed with at Hetton Colliery, and replaced by reciprocating

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engines. Then we have the directors of the Newcastle and Carlisle Railway, local men well acquainted with the results of locomotive running, deciding to work their new line by horses only. Joseph Tomlinson wrote that "Locomotion" would not "make steam," and its straight flue was replaced by a return tube. Theodore West, in his *Outline History* relates the difficulties there were in maintaining steam, and that the locomotives frequently stopped for want of it. As time passed hope and confidence gave way to doubts and fear. From the railway mania of 1825 much was expected, but not one single additional line was worked by locomotives for years, and the discouraging results of the Stockton & Darlington Railway were such that the Deputation appointed by the Liverpool & Manchester Railway Directors reported in favour of stationary engines. The Stockton & Darlington Railway tried to secure locomotives elsewhere, and applied to Matthew Murray, who declined, and eventually they commissioned their own engineer to build one. The failure was reflected in the action of so strong a supporter as Edward Pease, who wanted to withdraw from Stephenson's factory, and who wrote to Robert Stephenson—who was abroad—advising his return, or the works would be given up. Another partner, Thomas Richardson, wrote similarly.

This brings us to a further objection by Mr. Warren, that the statement that the results were such that the Directors of the Stockton & Darlington Railway all but decided to abandon steam in favour of horses. The statement was published by the editor of the *Practical Mechanics' Journal* in June, 1850, at a time when many of those interested in and conversant with the early railway days were alive. It was not contradicted at the time, nor so far as I am aware has any evidence since been disclosed to the contrary. Indeed, without improvement, the removal of locomotives would have been inevitable. The Company's shares had dropped in value; their funds were exhausted, people who had lent money were demanding its return, an attempt to float a new loan failed, and they were short of money to pay current expenses. Now all this time, unlimited quantities of coal, for which a market was available, were waiting to be led. In order to cope with the trade, the Company introduced additional horses, an ominous step which is shown in the Abstract of Accounts for the year ending June, 1827. If locomotives were cheaper, why had the Company not ordered more of them, and why revert to the more ancient type of haulage? The apparent saving of 30 per cent. in cost of engines over horses alluded to by Mr. Warren is not borne out by any evidence beyond the cautious Directors' Report that such "appears to be" the case. But as de Pambour says, the costs of engine and horse haulage were not separated on the railway. Coal cost from 2s. 6d. to 3s. 9d. per ton, and Elijah Galloway points out that "if the saving be so trifling, where is the advantage which steam carriages possess?" Even in the first half of 1828, when the Royal George

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was effecting a revolution in the coal leading, horses conveyed nearly half of the coal traffic.

Now we come to my assertion that Robert Stephenson induced the deputation of the Liverpool and Manchester Railway to insert in their report of March, 1829, an account of the work done by the "Royal George." It appears in the report by Messrs. Rastrick and Walker, and the figures given of coal consumption are very impressive:—

	lb.
Consumption of coal per ton of goods conveyed one mile at 11 miles per hour, Royal George	1.60
Do. Blenkinsop's engines, at 4 miles per hour	2.75
Do. Killingworth and Hetton engines, at 4 miles per hour	2.25

The experiment was reported to the deputation by Robert Stephenson.

It is correct that Robert Stephenson and Joseph Locke prepared a reply to the report, which was published, according to Robert Stephenson's biographer, in February, 1830, nearly a year later, and that the merits of the Lancashire Witch were therein mentioned. But this does not alter the fact that Robert Stephenson had previously drawn the attention of the deputation to the performance of the Royal George, nor is it just to say the Royal George was more powerful than the others merely because it was heavier. Other factors besides weight entered into the problem; engine design and details, improved type of boiler, increased heating surface and a perfect blast. It is pretty obvious that the inverted cylinders, with their direct action to the wheels, showed a considerable advance on the sunken cylinders with the pistons working upwards, and the overhead crossheads and rods which were the features of the first four Stockton and Darlington locomotives. And it must be remembered that the cylinder volumes in both designs were practically equal, the Royal George having cylinders 11in. by 20in. and Locomotion type 10in. by 24in.

In reference to the Sanspareil, it is hardly necessary to confirm Mr. Warren's remark that it was adjudicated to be over weight at the Rainhill competition. In spite of being 4 ton 15 cwt. instead of 4 ton 10 cwt., it was permitted to run so that the judges might see if its performance would merit their favourable consideration; with this matter Messrs. Stephenson had of course no concern. But is is no justification for their inferior workmanship which forced the engine to be withdrawn during the contest owing to the bursting of a cylinder cast by them.

I would like to add that my paper was prepared for this Society, not with the view of depreciating or discrediting the great work of the early locomotive builders, but of drawing particular attention to one of them concerning whom but little has hitherto been made public.

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Mr. H. W. Dickinson wrote that, since the reading of the paper, he had come across a MS. note-book of J. U. Rastrick,[1] recording particulars of locomotives and railways gleaned during a tour that he made in January, 1829, when he was preparing his report[2] to the Directors of the Liverpool and Manchester Railway, on the comparative merits of fixed and locomotive engines.

At that date, Rastrick saw the Royal George, of which he gives a sketch and description very clearly showing that equalising springs to the four front wheels of the engine were then fitted.

[1]In the Rastrick Collection, Goldsmiths' Economic Library, University of London.
[2]See p. 35, 74.

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The Centenary of Naval Engineering

A Review of the Early History of our Steam Navy.

By Eng. Capt. Edgar C. Smith, O.B.E., R.N.

(*Read at the Institute of Marine Engineers, Minories, E., March 30th, 1922.*)

Some explanation is perhaps necessary for the title given to this paper. It is found in the fact that on May 23rd, 1822, just a hundred years ago, the first steam vessel constructed in either of H.M. Dockyards was launched. This was H.M.S. "Comet." Yet the "Comet" was not the first steam vessel in the Navy. That distinction belongs to H.M.S. "Monkey," which, built by Evans of Rotherhithe, had been purchased in 1821. Though the "Monkey" was slightly the smaller of the two vessels, their engines, by Boulton Watt & Co., were practically identical; and with these begins the history of Naval Engineering.

It was not for want of advocates, however, that steam vessels had not found their way into the Navy earlier, for in the ten years that had passed since Bell had launched his "Comet" on the Clyde, many persons, including Bell himself, had pointed out to the Navy Board the advantages of steam. Through Sir Joseph Banks, steps had been taken in 1816 to fit out Captain Tuckey's exploring vessel the "Congo" as a steamer, but that attempt had ended in failure, and the engine ordered for the "Congo" was installed in Chatham Dockyard.[1] A Navy that had emerged victorious from the Napoleonic wars knew nothing of steam and the time was not ripe for innovations. That the barriers of inertia were at last broken down was largely due to Brunel and to Rennie, who first instituted towing trials, and it was also owing to Rennie that Oliver Lang was ordered to lay down the "Comet" at Deptford in November 1821.

While much has been written regarding the progress of naval machinery during the last sixty years, the same cannot be said of the first forty years. The present occasion therefore seems a suitable one for placing before this Society, a brief account of our earlier steam warships, of their machinery, and of the Engineers who built their engines or who had charge of them. This history, it is submitted, has more than a passing interest. The "Hood" with her 150,000 horse power, the "Tiger" and "Lion" with their engine room complements of 600, the great engineering branch of H.M. Navy with its distinguished record, all had their beginning in the insignificant "dirty old smoke-jacks," the engine

[1]Narrative of an Expedition in 1816 to explore the River Zaire (*i.e.*, Congo). By Captain J. K. Tuckey, R.N., 1818, p. xxiii.

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rooms of which were manned by workmen trained at bench and forge in the shops of Boulton and Watt, Maudslay, Napier and Penn.

The history of our steam navy may be divided roughly into five periods or stages marked by:

(a) The evolution of the paddle wheel frigate.
(b) The conversion of the three-decker into an auxiliary screw steamer.
(c) The complete substitution of steam for sails.
(d) The evolution of fast torpedo craft.
(e) The development of the high-speed battleship.

It is with the period covered by the development of the paddle wheel frigate that the present paper is concerned. At some future time it is hoped to give an account of the coming of the screw, and the endeavours made to convert the old wooden sailing line-of-battleships into efficient steamers.

Early Naval Steam Vessels.

Following hard upon the "Comet" and "Monkey," all built in the '20s, came the "Sprightly," "Lightning," "Meteor," "Echo," and others, the names of which will be found in Table I. in the appendix. Though at one time or another most of them were lightly armed they were little else than despatch vessels or tugs. Some of the earliest naval steamers were employed as post office packets. One of the most successful and one of the best known of them was H.M.S. "Lightning," a sectional model of whose machinery is in the Naval Museum at Greenwich. In 1824 she was sent from Portsmouth to accompany transports and bomb vessels for active service on the coast of Algiers.[2] Three years later "His Royal Highness (the Duke of Clarence) had the proud gratification of putting into commission the first steam vessel upon the Navy List."[3] This refers to the "Lightning," and her commander was Lieut. George Evans. At the same time the "Meteor" and "Echo" were placed on the Navy List. The "Lightning" was occasionally used as a yacht. When Queen Victoria went to Scotland she had her stopped for enquiries to be made regarding a prince who had taken passage to Ostend in her. *Punch* commemorated the incident with the jingle:

"Though Canute could not check the wave
When rapidly the tide was heightening,
Victoria her orders gave
And at her bidding stopped the 'Lightning.'"

One of the last tasks this famous little craft was used for was the deep sea research expedition of 1868, when she and the "Porcupine" were lent to the Royal Society.

[2] *Hampshire Telegraph*, 26th July, 1824.
[3] Naval Administration. 1827-1892. By Sir J. H. Briggs, p. 5.

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The "Echo" is noteworthy as being the first vessel in the Navy to be fitted with a so-called high pressure boiler. This was cylindrical and had a long cylindrical flue. It carried a pressure of 15lb. Her original boilers carried 3½lb. pressure and the change resulted in a reduction of coal consumed per month from 9,500 bushels to 5,000 bushels.

The "Meteor," on the 5th February, 1830, inaugurated the steam mail service between Falmouth and Malta and Corfu. Her sister packets were the "African," "Carron," "Columbia," "Confiance," "Echo," "Firebrand," "Hermes," and "Messenger." Sailing packets had taken three months for the double journey. In 1831 the "Messenger" went to Corfu and back in 36 days.[4]

By this time the decision had been taken to construct a steam fighting ship. The result was H.M.S. "Dee." Designed by Sir Robert Seppings and Oliver Lang, she was laid down at Woolwich in 1829 and launched in 1832. She was 704 tons and carried two 32pdr. 63cwt. and two 32pdr. 25½cwt. It was the model of her engines Henry Maudslay was busy with when Nasmyth became his private assistant at ten shillings a week.

Next came four vessels constructed to the design of the four master shipwrights at the different yards,[5] these vessels being the

"Rhadamanthus," built at Devonport, commissioned October, 1832.
"Salamander," built at Sheerness, commissioned November, 1832.
"Phœnix," built at Chatham, commissioned November, 1833.
"Medea," built at Woolwich, commissioned January, 1834.

All were about 800 tons and all were engined by Maudslay with engines of 220 h.p. They were not without their critics. Commander Otway referred to the "Phœnix, Salamander & Co." as being "most inadequate sea boats, beautiful to look at, taper-waisted as a wasp, and as sharp in the bow as the bill of a snipe; admirably calculated for running over a lake provided the blast does not exalt the rage of the billows." The "Medea," designed by Oliver Lang, was a successful vessel, and Lieut. Baldock, who served in her, has left an account of her first commission. Her captain was Commander H. T. Austin and her engineer Thomas Hamshaw, who from the "Medea" was appointed Chief Engineer of Malta Dockyard, a post he held for nearly forty years.

An event of great importance in the history of the steam Navy was the appointment in 1832 of Captain Sir William Symonds[6] to the office of Surveyor of the Navy. For fifteen years he dominated naval shipbuilding, constructing many remarkable sailing vessels, but remaining unprogressive regarding steam machinery and its adoption. His first steam sloops were most inadequately engined. The "Volcano" of 720 tons had engines of only 140 nom. h.p. A definite

[4]On the History of Paddle Wheel Steam Navigation. By Henry Sandham, Proc. I.Mech. E., March, 1885, p. 131.
[5]A History of Naval Architecture. By John Fincham, 1851, p. 331.

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advance was made with the "Gorgon" and her sister ship the "Cyclops," both of which were fitted with Seaward's "Gorgon" type of direct acting engine. These engines weighed 60 tons less than the equivalent side lever engines.

The building of the "Gorgon" coincided with the accession of Queen Victoria, and in that year Otway gave the classification of H.M. steamers thus:—

I.	II.	III.	IV.	V.
"Cyclops,"	"Dee,"	"Hermes,"	"Blazer,"	"Lightning,"
"Gorgon."	"Medea,"	"Firebrand,"	"Tartarus,"	"Meteor,"
	"Rhadamanthus,"	"Firefly,"	"Columbia,"	"Confiance,"
	"Phœnix,"	"Megæra,"	"Pluto,"	"African,"
	"Salamander,"	"Spitfire,"		"Echo,"
	"Messenger."	"Volcano,"		"Alban,"
		"Flamer."		"Carron,"
				"Comet."

THE DEVELOPMENT OF THE PADDLE WHEEL FRIGATE.

The highest development of the paddle wheel warship took place in the decade 1840-1850. Table II. contains some particulars respecting all the ships with over 200 nom. h.p. Space does not permit of more than a brief notice of a few of these.

The "Vesuvius" and "Stromboli," engined by Napier, and the "Hecate" and "Hecla," engined by Scott & Sinclair, were the first vessels in the Navy to have their machinery built on the Clyde. Save for the "Spiteful" and "Harpy," they were the last of the larger vessels to have side lever engines, a type that long remained a favourite for merchant ships. The "Vesuvius" was contemporary was the first Cunarders. Both she and the "Stromboli" were good steamers, and their success provided Napier and his London agent with a strong argument when trying to divert to the Clyde some of the patronage hitherto given to firms on the Thames.[7] Captain Erasmus Ommanney, who had been one of Napier's "apprentices," writing from the "Vesuvius" in 1843, speaks of "the pleasure of being carried so far by a pair of your incomparable engines which are almost as efficient as when they left Glasgow."

Of the vessels built in 1841, the "Driver"[8] is noteworthy as being the first steam vessel to circumnavigate the globe,[9] while the "Devastation" was the first to be fitted with Maudslay's twin cylinder direct acting engines patented by Joseph Maudslay and Joshua Field in 1839. She also had what were known as double-storeyed flue boilers, a type originally fitted by Brunel in the "Great Western."

[6]Life of Sir William Symonds and Dict. Nat. Biog.
[7]Life of Robert Napier. By James Napier, 1904, Chap. VI.
[8]When the "Driver" left England her boilers were fitted with mechanical stoking apparatus. This proved unreliable, and was landed at the Cape.
[9]A Sketch of the Origin and Progress of Steam Navigation. By Bennet Woodcroft, 1848, p. 88.

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In 1843 the experiment was made of converting a sailing frigate into a steamer. The vessel was the "Penelope," 42 guns, built at Chatham in 1829. She was cut in halves, lengthened 65 feet and fitted with Seaward's "Gorgon" engines of 650 nom. h.p., her ultimate tonnage being 1,600-1,700 tons. Her machinery, paddle wheels, water, etc., weighed 435 tons, and she could stow 500 tons of coal. She was the first vessel in the Service fitted with tubular boilers, and she also had Hall's surface condensers, which had previously been tried in the "Megæra." The condensers, according to Gordon, had 9,000 tubes 6ft. 8in. long and 0.3in. diam. In the same year the first "Firebrand" was lengthened and re-named "Black Eagle" and fitted with Penn's oscillating engines, and the second "Firebrand" was built and fitted with tubular boilers having 2,250 brass tubes, 2in. internal diameter and 5ft. 1in. in length. Lieut. Gordon said these boilers gave the highest amount of evaporation that had been attained by any steam vessel up to that time.

In 1844 the "Samson" was engined by Rennie with direct acting engines having the shifting link motion. The "Retribution" of the same year had engines of 800 nom. h.p. by Maudslay. These, however, proved too large and heavy, and she was re-engined by Penn with oscillating engines of 400 nom. h.p. A trial in 1850 gave a speed of 10.4 knots with 1,002 ind. h.p. using all four boilers, while with one boiler the engines developed 226 ind. h.p., and gave a speed of 6.22 knots.[10] The year 1844 also saw the remarkable attempt of Lord Dundonald —the great seaman and inventor—to drive a ship with a rotary engine. This was the "Janus," built at Chatham. He designed ship, boiler and engines, but the machinery was a failure.

The following year saw the launch of the largest and finest of all our paddle wheel vessels, H.M.S. "Terrible."[11] Built at Deptford from the designs of Lang, her displacement was about 3,000 tons, her nom. h.p. 800, and her ind. h.p. nearly 2,000. She was 226 feet long, 43 feet wide, and at one time carried an armament of seven 68-pdrs., four 10-inch, ten 8-inch, four light 32-pdrs. Her timbers were fitted so closely together as to make a watertight hull before the exterior planking was fitted, and her engines were the largest of the type fitted in a man-of-war. When she joined the squadron off Lisbon, Admiral Sir William Parker wrote, "The 'Terrible' is a noble vessel and answers completely."[12]

The designing of the "Janus" by Dundonald and the "Terrible" by Lang marks the decline of the authority of Sir William Symonds and the end of official exclusiveness.[5] This was further accentuated in the case of the "Odin" and the "Sidon" of 1846, the former of which was designed by the well-known master shipwright, John Fincham, while the latter, built more or less on the lines

[10] "On High Speed Steam Navigation." Proc.Inst.C.E., 10th March, 1857. Remarks in discussion by Edward Humphrys.

[11] Catalogue of Naval and Marine Engineering, Science Mus., South Kensington, 1911, p. 24.

[12] Life of Admiral Sir William Parker. By Admiral Phillimore, Vol. III., p. 98.

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of the "Odin," was altered to meet the views of Admiral Sir Charles Napier, who had for years been endeavouring to get his ideas put into practice. Both vessels were designed to carry guns as a main deck armament, they both carried themselves frigate-wise by painted chequered sides, whereas all other steam vessels at that time were painted black; and among other innovations the "Sidon" had tanks for coal bunkers which could be filled with water as the coal was used, so as to maintain the same draught. Attempts were also made to protect the machinery. The "Sidon," however, proved very crank and earned for herself the sobriquet of "Side-on."

It may be noted that practically all these vessels included in Table II. were built of wood, the exceptions being distinguished in the tables by the letter I.

Generally speaking, the speed of the larger ships referred to was about 10 to 11 knots. Greater speeds were attained with four vessels built originally for the Holyhead and Kingstown Station. Of these the "Caradoc," engined by Seaward, had a speed of 14 knots; the "Llewellyn," engined by Miller, Ravenhill and Salkeld, a speed of 15.2 knots; the "Banshee," with Penn's oscillating engines, a speed of 16.3 knots; while the "St. Columba," built by Laird, had a speed of 14.2 knots. The "Llewellyn's" boilers carried a pressure of 20lb., while the pressure in the other three vessels was 14lb. All four vessels were about 650-700 tons and 350 nom. h.p.[13] The "Llewellyn" and "St. Columba" had a very short life in the Service, being sold to the City of Dublin Steam Packet Company in 1850.

The "Birkenhead," built in 1845 by Laird, was the fine iron frigate which, when carrying troops on February 27th, 1852, struck upon a rock off Danger Point, Aljou Bay, and was lost with over 400 souls.

Early Marine Engine Builders.

In his review of the progress of marine engineering contained in his presidential address to the Institution of Civil Engineers in 1846, Sir John Rennie mentioned, as being among the pioneers of this branch of industry, Boulton and Watt, Maudslay, Field, Robert and David Napier, Miller, Ravenhill, Seaward, Rennie, Scott, Fawcett, Penn, Jessop, Glynn, Barnes, and others. Nearly all of these contributed also to the development of naval engineering. Boulton and Watt had built the engines for the "Congo" in 1816 and to them went many of the earliest orders. The Butterley Iron Works of Derby, with which Jessop, Miller, Barnes and Glynn were associated, also built some early engines. But it is neither to these famous old English firms or to the birthplace of the steamboat —the Clyde—that one turns to trace the history of the man-of-war's steam engine, but rather to the banks of the Thames. First in the field came Henry Maudslay

[13] Fincham, 336.

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(1771-1831), who having made a reputation at the works near Oxford Street, London, founded in 1810 the works at Westminster Bridge Road. Six years before this he had been joined by Joshua Field (1787-1863), and ultimately four of Maudslay's sons were connected with the works. To Joseph Maudslay (1801-1861), the fourth son, belongs the credit of reviving interest in the oscillating engine, and in 1839 with Field he patented the twin cylinder engine, which was extensively used. He also brought out the annular engine, an example of which was to be seen in H.M.S. "Princess Alice." Charles Sells (1820-1900), said to be the most successful designer of marine engines of the last century, joined Maudslay's in 1837, and in 1847 was the first head of the designing department. Twelve years after Maudslay moved to Lambeth, Joseph Miller (1797-1860) joined hands with John Barnes (1798-1852)—both were old Soho apprentices—and in 1822 opened a shop at Glasshouse Fields, Ratcliff. In 1824 John Seaward (1786-1856) founded the Canal Iron Works at Millwall. The first naval vessel engined by Miller was the "Blazer," Seaward about the same time obtaining the order for the engines of the "Volcano." Seaward was one of the most progressive engineers of his time. He not only introduced the "Gorgon" or direct acting type of paddle wheel engine, but he developed the tubular boiler, devised brine nozzles and tanks, invented a telescopic funnel and for some years was one of the chief builders of naval engines. Miller's services were also of a pioneering character. His partner left him in 1835, Barnes afterwards playing an important part in the development of steam navigation in France. Miller was then joined by Ravenhill, and in 1846 the firm became Miller, Ravenhill and Salkeld.

The connection of John Penn (1805-1878) with the Navy began with his offer to re-engine the Admiralty Yacht "Black Eagle" (late "Firebrand") with engines of the same weight but of much greater power than the original ones. The story of the reception of his uninvited tender is found in the autobiography of Sir John Rennie. This was in 1843, and the association thus began lasted Penn's lifetime. His reputation was second to none and his services to the country during the Crimean War were of the highest order. Penn's works at Greenwich had been founded by his father about 1800. Of the other London marine engine builders, mention may be made of George Rennie (1791-1866), who in the Holland Street Works at Blackfriars built engines for the "Samson," "Bulldog" and "Oberon," and of Edward Humphrys (1808-1867), who, after holding the post of Chief Engineer of Woolwich Dockyard for two years, in 1852, with Tennant and Dykes, founded the Deptford Pier Works. Humphrys, however, supplied no engines for paddle wheel warships.

Of other marine engineers connected with the Navy, Robert Napier (1791-1876), of Glasgow, has already been referred to in connection with the "Stromboli" and "Vesuvius." He also engined the "Thunderbolt" and "Harpy,"

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and built and engined the three iron paddle wheel gunboats "Bloodhound," "Jackal," and "Lizard." His right-hand man for many years was David Elder (1785-1866), the father of John Elder. Scott and Sinclair, of Greenock, supplied the machinery for the "Hecate," "Hecla," and "Spiteful." Fairbairn, of Manchester, built the direct acting engines for the "Vulture," "Odin," and "Sidon"; Fawcett, of Liverpool, built the engines of the "Inflexible," "Medusa," and "Merlin"; while Rigby engined the "Fury."

Of the 25,000 total nom. h.p. of the vessels in Table II., the collective nom. h.p. of Penn's engines was 2,070, of Miller's 2,860, of Maudslay's 4,370, and of Seaward's 6,770.

Naval Engineering during the '30's and '40's.

Though seagoing engineers have never, to any extent, been given to writing steam manuals or recording their experiences, there were in the early days of the steam navy many naval officers, not engineers themselves, who took a great interest in steam and who not only studied Tredgold and turned up their sleeves in Napier's and Seaward's shops, but who fortunately wrote works on the marine steam engine. In 1828, the year before he sailed north in the little steamer "Victory," fitted with Ericsson's heart-breaking novelties in the way of imperfectly tried machinery, Captain Sir John Ross published his "Treatise on Steam Navigation." His experiences with the "Victory's" engines are however contained in his "Narrative of a second voyage in search of the North-West Passage," published in 1835. The ship left Gravesend May 23rd, 1829, and in October of that year, so troublesome had the machinery been, that it was taken out, lock, stock and barrel, and placed on the ice. Next to Ross's book on the steam engine came that by Commander Robert Otway entitled "An Elementary Treatise on Steam." There were three editions, which appeared in 1832, 1834, and 1837. Otway had held command of the "Comet" and the "Echo," and it was while he was captain that the "Echo" had her high pressure boiler fitted.

In 1838 we have the first literary effort of a naval engineer—the memoir, "On Marine Boilers,"[14] by John Dinnen, who may be termed the father of naval engineers. The essay contained the outcome of his experiences as Chief Engineer of the "Lightning" (1828-31) and "African" (1831-36). Following Dinnen came Commander Spencer Robinson, afterwards Controller of the Navy, with his book, "The Nautical Steam Engine," 1839. That same year Captain Basil Hall, writing in the *United Service Magazine,* advised young officers to turn their attention to steam, and told them to take off their coats and put on paper caps and submit to the companionship of thorough-going workmen in Maudslay's and Napier's workshops. In 1843 Captain W. J. Williams, who had lectured on steam

[14]The Steam Engine. By Tredgold, Vol. III., 1852.

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in the Royal Naval College at Portsmouth, published "A Steam Manual for the British Navy," and two years later Lieutenant W. E. Gordon published "The Economy of the Marine Steam Engine," in which are to be found some particulars of the "Driver," in which he went round the world. Lectures had been given for some years at Portsmouth before Williams wrote his manual, and the "Messenger," and then the "Bee," had been used for practical instruction. The first lectures appear to have been given voluntarily, but about 1841 Thomas Brown, one of the first to rise to the rank of Chief Engineer, was appointed for that duty; and in 1847, with Thomas J. Main, the mathematical professor, he published "The Marine Steam Engine," which long remained the text book for the Navy.

It is from these books and the works of Murray, Bourne, Tredgold, Hoblyn and others that the following notes on practical engineering in the '30s and '40s have been compiled.

For the first twenty years of the steam Navy all boilers were of the flue type. Externally the boiler was box-like. Boilers were often shaped to fit the vessel. In a flue boiler the gases from the furnace passed along a winding passage, the ceiling and walls of which provided the heating surfaces. The flues were separated by water spaces. These were four or five inches wide while the flues were 16 or 17 inches wide. The flue in some cases had a length of 60 feet. Leakage at the bottom of the flue was very frequent. Dinnen suggested cementing and tiling, Maudslay proposed tinning the bottom plates. Flue boilers were structurally weak, they were heavy, contained a great volume of water, and were only fit for very low pressures. Sometimes the whole boiler was constructed of copper. The height of the water was shown by a copper float and indicator, then by glass tube gauges. Safety valves were always of the dead-weight type. They could usually be lifted by hand. The waste steam pipe ended in a rose and bulb arrangement to prevent the condensed steam falling on the crew and paint work. Reverse valves, or internal safety valves, were fitted to prevent the formation of a vacuum in the boiler. Pressure and vacuum gauges up to the 'sixties were iron U tubes, partly filled with mercury, on the open end of which rested a float. When a boiler was to be tested, oatmeal or similar substances were used in considerable quantities. Dinnen remarks on the numerous "weeps" and "channels," of which no notice was taken. Tubular boilers when first fitted were criticized, because the flaming at the funnel which occurred was dangerous to the rigging of a ship being towed alongside.[15] The pressure in use remained very low. From 3½ lbs. it gradually increased in forty years to 20 lbs. Especially interesting on this point is the paper read by Seaward to the Institution of Civil Engineers in 1849, "On the Employment of High Pressure Steam Working Expansively." The discussion was taken

[15]Life of Sir William Parker, p. 331.

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part in by Rennie, Scott Russell, Farey, Perkins, Joshua Field, and other stalwarts of that heroic age. The Admiralty had asked the opinion of various makers, and Seaward had recommended that "the steam employed in the Navy should not be of greater pressure than 10 lbs. per square inch." This accorded more or less with the general view.

The successful working of these low pressure boilers with salt water called for great care. Blowing down was of the first importance. Instructions in 1844 said the engineer was to draw off a small quantity of water in a saucepan. "He is then to dip a common brewer's thermometer into it and boil it. Should the boiling point exceed 215 degrees there is danger of incrustation." In early days ships at sea every third or fourth day put out the fires and emptied the boiler. This fell into abeyance, and blowing down every two hours became the rule. Dinnen lays particular stress on the need for caution. If the blow-down cocks jammed, the water could be blown through the hand-pump, or, according to Murray, "a usual plan is to knock out a rivet from the bottom of the boiler."[16] Brine pumps were introduced by Maudslay, brine tanks and valves by Seaward. Feed heating came into use quite early, an annular tank being placed round the funnel. From this the water sometimes found its way into the boiler by gravity. When brine pumps were in use, the brine passed through a refrigerator, which cooled the brine and heated the feed. To prevent incrustation charcoal, sawdust, and other substances were recommended, while to prevent priming tallow was put into the boiler. Firing a musket up the funnel was a common method of dislodging the soot.

For the first twenty years naval vessels had side-lever engines. Napier continued to build such engines for Atlantic liners till 1860. These engines were reliable, but took up much space and were heavy. Pistons at first were packed with hemp gasket. The long D slide valve, invented by Murdock, was balanced and was driven by a loose eccentric. Stopping and starting was done by moving the slide by hand. Jet condensers were the rule, and a vacuum was obtained by filling the condenser with steam through the blow-through valve and then turning on the injection. The snifting valve, which allowed the air in the condenser to escape when the condenser was flooded with steam, was first placed in the air pump. David Elder removed it to the condenser.[17] It was placed low down, and could on occasion be fixed open so that the air pump could pump out the bilge. The regulation of the injection water had to be carefully attended to. Lines were scored across the frames to test whether the engines remained in line with one another. The parallel motion, the valve levers, the stops on the shaft

[16]Rudimentary Treatise on Marine Engines. By Robert Murray, 3rd edition, 1858, p. 70.

[17]Memoir of David Elder. Trans. of I. of E. & S. of Scotland, Vol. IX.

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all provided problems for the Engineer in charge. Fresh water for the use of the crew was obtained from the cylinder jacket. The "African" dispensed with eight water tanks by this plan, and Otway suggested the use of a tank and a pump for distributing this hot water about the ship. The first vessel in the Navy to have a surface condenser was the "Megæra." She had the five-fold combination—an air pump, a circulating pump, a surface condenser, an evaporator, and a steam saver—according to Samuel Hall's patent of 1836.[18] At first it was not worked correctly, but after Hamshaw, of Malta, had taken the matter in hand it was quite successful, and it was reported on in 1842 by the triumvirate of early naval engineering, Parry, Ewart, and Lloyd.[19] Unfortunately, the "Megæra" was wrecked in 1843, and though the surface condenser was tried in the "Penelope," it did not come into general use till twenty years later.

The cumbrous nature of the side lever engine led to the invention of various types of direct acting engines, such as the "Gorgon" engine of Seaward, the twin cylinder engine of Maudslay, the direct acting engine of Fairbairn, Miller, Boulton & Watt, and others. The oscillating engine invented by Murdock, and improved by Manby, was taken up by Maudslay, but its final success was mainly due to Penn. David Napier's steeple engine does not appear to have been used in any of H.M. vessels, except the "Firequeen."

Usually the common type of paddle wheels was used. Feathering paddles were fitted in various ships, as also was the cycloidal wheel of Field, in which the paddle boards were divided into strips and arranged in the arm in a cycloidal curve. It being of paramount importance that all war vessels should maintain their sailing qualities, the reefing of the paddle floats, the unshipping of the floats or the disconnecting of the paddle wheels so that they were free to revolve, were matters of considerable importance, and much attention was paid to this. Braithwaite, Seaward, and Maudslay all introduced methods of disconnecting. Brakes were also fitted for holding the paddle wheels when required, while quite a number of officers expended ingenuity in designing paddle-box boats, which were carried upside down over the paddle wheels.

Early Naval Engineering Personnel Afloat and Ashore.

As the Engineers who served in the early Steam Navy were given no official standing, and were free to come and go almost as they pleased, little is known of them. They were certainly not regarded with approval by their shipmates. In 1827 this antagonism found expression in a somewhat curious manner. In that year the carpenters held a meeting at Portsmouth, at which they passed a

[18] A Manual of the Steam Engine. By Richard D. Hoblyn, 1842, pp. 212, 227, and Appendix II.

[19] Warrant Officers' Manual.

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resolution to the effect that it was "derogatory to the position of Warrant Officers, who had been indentured in His Majesty's Dockyards, to have charge of the engine men and their stores of oil, coals, etc.," and the Chairman was requested to respectfully lay the matter unofficially before the Port Admiral.[19] What the sequel was does not appear. The first official regulation regarding the engineers seems to have been connected with an order of 1835, which required Commanding Officers of steam vessels to send in monthly reports about their steaming and sailing and defects; the last clause but one required remarks on the "Conduct of the Engineers during the month."[20]

The Engineering Branch was first organised in 1837, regulations being issued in July creating three grades of engineers and four grades of engineer boys for training. The engineers were to be warrant officers like gunners, boatswains, and carpenters, and were to rank after the latter. The pay of a 1st class engineer was fixed at £9 12s. a month, while 2nd and 3rd class engineers received £6 16s. and £4 18s. respectively. The boys, who were to be trained partly in Woolwich Dockyard and partly afloat, got from 14s. 6d. to £1 14s. a month. A year later their Lordships, being convinced from experience that this pay was insufficient to secure the services of competent persons as engineers, and "having found that within the last sixteen months numerous persons of this class have voluntarily quitted their situations, doubtless for want of sufficient inducement to remain," raised the pay of the three classes of engineers to £12, £8, and £5 6s. The uniform of the engineers was the same as the other warrant officers, but in 1841 an engineer's button was introduced, having a steam engine with a crown above embossed on it. In 1842 a medal for engineers of the first class was instituted for ability and good conduct. Only seven were awarded.[21] The ribbon was dark blue with white edges. To further the training of engineer boys, in 1843 the old barque "Sulphur" was allocated as a school ship. She did this duty for three years, and the boys who passed through her became known as "Sulphur Engineers." Engineer Robert Roughton for some years was instructor in steam at Woolwich.[22] While there he made experiments on the flow of steam from nozzles.

The regulations of 1837 held good for ten years. By an Order in Council of February 27, 1847, the status of the engineer was greatly improved. "With a view of providing and maintaining an effectual body of engineer officers for the Navy," and "having carefully compared their position and allowances with those of the engineers in the East India Company and the Mercantile Service generally,

[20] An Autobiographical Memoir of Sir John Barrow, p. 445.
[21] Payne's "Handbook of British Orders, etc."
[22] A Treatise on the Economy of Fuel. By Capt. A. P. Ryder, 1852, p. vi.

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as well as those in the service of foreign Powers," the Admiralty reorganised the engineers into seven grades, viz. :—

Inspectors of Machinery afloat,
Chief Engineers, 1st, 2nd and 3rd Class,
Assistant Engineers, 1st, 2nd and 3rd Class,

ranking with, but after, the Masters of the Fleet, Masters, and Second Masters, who then formed the navigating branch of the Service. The rates of pay were :—

Inspector of Machinery afloat	£25	0	0	a month
Chief Engineer, 1st Class	£20	0	0	,,
2nd Class	£16	0	0	,,
3rd Class	£14	0	0	,,
Assistant Engineer, 1st Class	£12	0	0	,,
2nd Class	£9	10	0	,,
3rd Class	£8	0	0	,,

The grading of the engineers took three or four years, for though some Chief Engineers are found under the ships they were serving in, in the Navy List of 1849, full seniority lists did not appear till 1852. Assistant engineers' names were not given at all till 1870. The regulations of 1847 formed the basis of the organisation of the engineering branch till the present century.

Short biographical sketches of two of the earliest engineer officers may be of interest. John Dinnen (1808-1866),[23] already spoken of, was the son of the Master Founder of Portsmouth Dockyard. From the Grammar School he became an apprentice to Goodrich, the master mechanist, and as has been mentioned, served in the "Lightning" and "African." For ten years he was then foreman at Woolwich, and in 1847 became the first Inspector of Machinery afloat. Speaking French and Italian fluently, full of anecdote, with a ready pen, Dinnen was an ornament to his profession, and his services were much sought after. He met his death through a cab accident outside the Admiralty, and the inscription on his tomb in Highgate cemetery truthfully says he died "in the midst of his hard labours, having devoted a life of thirty-nine years in bringing Her Majesty's steam Navy to its present important position among the nations." Ten years junior to Dinnen, Thomas Palmer Baker,[24] was one of six apprentices of Goodrich, all of whom were intended for naval service. From Portsmouth Yard he passed in succession to the "Meteor," "Comet," "Hermes," "Flamer," "Salamander," and "Devastation," and in 1844 became the engineer of Queen Victoria's first steam yacht, the "Victoria and Albert." During the Black Sea campaign he was head of his department in the Mediterranean, erected a factory at Constantinople and earned the good opinion of every admiral under whom he

[23] Obit. notice, Annual Report Inst.C.E., Dec. 18th, 1866.
[24] Report of Dockyard Economy Committee, 1859, Ans. 1991.

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served. In 1856 he became Chief Engineer of Chatham Dockyard. For his services in the war he was made a Knight of the Legion of Honour and received the Order of the Medjidie, and after his retirement in 1869 he was somewhat tardily awarded the C.B.

No sketch, however brief, of the early naval engineering personnel would be satisfactory without some reference to the civilian engineers—Lloyd, Ewart, Murray, Atherton and others—who were connected with the steam factories at the dockyards. Lloyd,[25] like Dinnen, was a Portsmouth Grammar School boy, but instead of being trained as an engineer he passed through the School of Naval Architecture. Quite early in his career he made a study of the steam engine, and was detailed for duty with the steam packet service. In 1833, at the age of 30, he was gazetted Inspector of Machinery at Woolwich. Lloyd's experience apparently not being considered sufficiently great, two years later an Order in Council led to the appointment of Peter Ewart[26] as Chief Engineer of the Dockyard, with the "salary of six hundred and fifty pounds a year (which is equal to that of a master shipwright)."[27] No fault could be found with Ewart on the score of age or experience. He had been John Rennie's first apprentice and had erected engines for Watt. For forty years he had been a Manchester manufacturer. When he came to Woolwich he was 68 and he was Chief Engineer till he was 75, when he met his death through a blow from a chain which broke when a boiler was being lifted. In 1837 another order[28] sanctioned the appointment of Captain Sir Edward Parry as Comptroller of the Steam Department at the Admiralty, a post he was succeeded in in 1846 by Captain Alexander Ellice. In the following year (1847)[29], circumstances having rendered it absolutely necessary that the Admiralty Department should be extended "so as to admit of the same being carried on in London independent of the steam factory at Woolwich," Lloyd, who had succeeded to Ewart's office, was transferred to London, the first Admiralty staff including:

A Chief Engineer (Thomas Lloyd), £700;
(With an allowance in lieu of a house, £200);
Assistant Engineer (Robert Hughes), £500;
First Draughtsman (James Wright), £250;
Second Draughtsman (John S. Holland), £150;
First Writer and Calculator (Eugene Sweny), £150;
Second Writer and Calculator (F. C. Ogle), £80;
Chief Clerk, £600.

[25]Obit. notice, Trans. I.N.A., 1876.
[26]Biog. notice, Memoirs of Lit. & Phil. Soc., Manchester, Vol. VII., 1846, and James Walker's Presidential Address, Inst.C.E., 1843.
[27]Order in Council, 13/5/1835.
[28]Order in Council, 19/4/1837.
[29]Order in Council, 24/4/1847.

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Lloyd's successors at Woolwich were successively Charles Atherton, Edward Humphrys and John Trickett, who was Chief Engineer when the Yard closed down in 1869. The factory, foundry and offices there, built in 1838 under the supervision of the veteran Peter Ewart, are still standing. The steam factories at Portsmouth, Devonport and Chatham date from 1846; Andrew Murray[30] was Chief Engineer of Portsmouth from 1846 to 1869, while Atherton[31] and Trickett[32] were connected with Devonport. Murray was a student of Edinburgh University; Atherton a senior wrangler and graduate of Cambridge. Murray had been trained under Fairbairn, while Atherton was a pupil of Telford. The first Chief Engineer of Chatham was Alexander Laurie, of whom little is known, while the first Chief Engineer of Sheerness was George Blaxland,[33] a sound practical engineer and the inventor of a screw propeller.

The Paddle Wheel Warship in Peace and War.

Having thus dealt—far less adequately it is feared than the subject deserves—with the matériel and engineering personnel of our first steam Navy, it remains to say something regarding the part the paddle wheel vessels played in naval affairs.

The first case of the use of a steam vessel as part of a fighting force was that of the "Diana," a small craft which was employed in the Burmese War in 1824. In the same year the *Hampshire Telegraph* records the voyage of the "Lightning" to Gibraltar and Algiers. Eager minds saw the potentiality of such vessels, and in 1826 Captain Napier (afterwards Admiral Sir Charles Napier) suggested their use against the pirates in the Ægean Sea. The Battle of Navarino in 1827 was, however, fought entirely between sailing ships. In 1828, that is twenty-one years after Fulton's success with the "Clermont" and fourteen years after he had built the "Demologos," there was still a great body of opinion against steam vessels being employed in war time. Approached by Mr. Hay on behalf of the Colonial Office with a request for a steamer to convey mails between Malta and the Ionian Islands, Lord Melville, the First Lord of the Admiralty, replied that he "regretted the inability of my Lords Commissioners to comply with the request of the Colonial Department, as they felt it their bounden duty, upon national and professional grounds, to discourage to the utmost of their ability the employment of steam vessels, as they considered that the introduction of steam was calculated to strike a fatal blow to the naval supremacy of the Empire; and

[30] Obit. notice, Annual Report Inst.C.E., 17th Dec., 1872.
[31] Obit. notice, Annual Report Inst.C.E., 1874-75, and Report on Dockyard Economy Committee, 1859.
[32] Obit. notice, Annual Report Inst.C.E., 1888-89.
[33] Report Dockyard Economy Committee, 1859.

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to concede to the request preferred would be simply to let in the thin edge of the wedge, and would unquestionably lead to similar demands being made upon the Admiralty from other departments."[34] Two years later the overseas steam mail service was actually started. In 1830 the French Navy used their first steamer, the "Sphynx," in operations on the African coast, and in 1832 our steamers, the "Dee" and "Rhadamanthus," joined the sailing fleet in blockading the coast of Holland. Many admirals were like Sir George Cockburn, who declared that "since the introduction of steam vessels he had never seen a clean deck, or captain who when he waited upon him did not look like a sweep"; but there were others who agreed with Sir Thomas Hardy, who a week before he died at Greenwich remarked, "Some people laugh at science, but science will alter the whole character of the Navy; depend upon it, steam and gunnery are in their infancy."

The value of a powerful steam vessel as a component of a fleet was exemplified in the case of the "Medea." In February, 1835, the Mediterranean Fleet was weatherbound in Malta harbour. A gale from the north-east was blowing, and the heavy swell rolling in the entrance made it impracticable for ships to beat out. The fleet being urgently required, the "Medea" raised steam and in turn towed the "Caledonia," 120 guns, and five 80-guns ships from their moorings to sea, an operation which was effected in 4 hours 10 minutes, "after which the fires were extinguished on board the 'Medea,' and she pursued her course as a sailing vessel in company with the squadron, the whole cost of coals and other engine stores expended on this occasion amounted only to £3 6s. 0d."[35]

Passing over the operations on the coasts of Spain and Portugal in the '30s, and other incidents, we come to the first occasion when steam vessels were employed in any considerable numbers, viz., the Syrian campaign of 1840. Official opinion had by this time altered, and the view was that when fleets met in action, "the first battle would be in favour of the fleet with the greatest number of steamers"; one admiral expressing the opinion "that steamers, if judiciously conducted, have the power to inflict merciless wounds with impunity, so that a first-rate may be bled to death, if I may say so, without receiving a shot in return."[36] Engaged in the operations on the coast of Syria were the "Cyclops," "Gorgon," "Hecla," "Hecate," "Medea," "Phœnix," "Stromboli," and "Vesuvius," six of which took part in the bombardment of Acre. Of their general usefulness, Admiral Stopford wrote from Beyrout, "The steam vessels have been immensely useful in constantly moving along a great extent of coast

[34]Naval Administrations, 1827-1892. Briggs, p. 9.
[35]Memoir of Her Majesty's Steam Ship "Medea." By Lieut. Thomas Baldock, 1838.
[36]Letters of Admiral Sir Thomas Byam Martin, p. 156.

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with troops and arms, and taking part in the attacks upon the different forts."[37] From this onwards no naval operations of any size were carried out without the aid of steam vessels.

Though the "Nemesis"[38] belonged to the Navy of the East India Company, and not to the Royal Navy, her unique character and services justify some mention of her. Constructed of iron by Laird, she was the first iron steamer to carry guns and to round the Cape. Of about 700 tons burden with engines of 130 h.p. by Forrester of Liverpool, she was built and launched in three months. She was divided into seven watertight compartments by iron bulkheads and had two drop keels. Her armament consisted of two 32-pdrs. On March 28th, 1840, she left Portsmouth, and after an adventurous voyage reached Cape Town. Continuing her voyage eastward, she broke a paddle wheel, and before she reached Delagoa Bay had developed two vertical cracks in her side plating extending 7 feet downwards from the deck. At Delagoa the fractured plates were renewed, the vessel was strengthened by wooden beams, and after visiting India she joined the China fleet off the Bogue ports. Known among the Chinese as the devil ship, she did excellent work in the war, which led to the ceding to us of Hongkong and the opening of the treaty ports. She carried six engineers, of whom Colin M'Dougal was killed, while her commanding officer was Lieutenant William Hutcheon Hall, a student of steam, who by his exertions rose from the lower deck to be an admiral.

The year 1842 was marked by the departure from England of the "Driver," which during a commission lasting nearly five years visited the Cape, China, India, Australia, New Zealand, and South America, circumnavigating the globe and travelling 75,696 miles.[39] Her performance was rivalled by that of the "Inflexible," which in a three years' commission (1846-49) sailed 4,392 miles, steamed 64,477 miles, and consumed 8,121 tons of coal.[40]

While these vessels were thus demonstrating the practicability of sending steamers on long voyages, others were taking part in warfare in the River Parana and elsewhere. In the expedition undertaken jointly by the French and British against the Argentine in 1845-46, the British fleet was accompanied by the steamers "Gorgon" and "Firebrand" and the French by the "Fulton," a vessel of 650 tons. At Obligada, a considerable distance up the Parana a boom of chains and boats had been constructed, and in the destruction of this and the batteries ashore all the vessels received a good deal of injury. The "Fulton," it is said, received 56 heavy round shot in her paddle wheels and sponsons, and one wheel

[37]United Services Magazine, 1840.
[38]Narrative of the Voyage and Services of the "Nemesis." By W. D. Bernard, 1844.
[39]Rudimentary Treatise on Marine Engines. By Robert Murray, 1858, p. 136.
[40]Life and Letters of Admiral Sir B. J. Sullivan.

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was reduced to a large mass of iron and splinters. In spite of this, when the boom was cut, she went up river with her one remaining paddle, and repassed the batteries to tow up some other vessels. "Though three round shot went in among her engines, they did no damage.[41]

For ordinary fleet actions at that time it was considered that the great value of steam vessels would be to tow the sailing line of battleships into and out of action, and at the bombardment of Sebastopol in the Black Sea in 1854 most of the paddle wheel frigates were so used. When the point was under discussion, Lord Auckland wrote to Admiral Sir William Parker, C.-in-C. of the Mediterranean in 1847:—

"You know how favourite a notion it is with me that every strong ship shall have her attendant steamer, and I think that your squadron may consist of:

'Hibernia,'	'Terrible,' 800 h.p.	'Canopus,'	'Dragon,' 560 h.p.
'Trafalgar,'	'Retribution,' 800 h.p.	'Superb,'	'Centaur,' 540 h.p.
'Rodney,'	'Sidon,' 560 h.p.	'America,'	'Gladiator,' 430 h.p.
'Albion,'	'Avenger,' 650 h.p.	'Thetis,'	'Scourge,' 430 h.p."

And he continues, "I attach infinite importance to the combined movements of steamers and sailing vessels, not only for material support, but also in the economy of means by the management of fuel."[42]

Sir Charles Napier's Channel fleet of the same year consisted of:

Ship.	Men.	Guns.	Ship.	Men.	Guns.
"Howe"	850	120	"Odin"	270	12
"Caledonia"	850	120	"Avenger"	250	6
"St. Vincent"	850	120	"Dragon"	195	6
"Queen"	800	110	"Vixen"	160	6
"Vengeance"	645	84	"Stromboli	160	6

The "Avenger," which appears in both these squadrons, was a fine new ship commanded by Napier's son, Captain Elers Napier. Detached from the Channel fleet, she was on her way to Malta, when, on the night of December 20th, 1847, during a terrific gale, she ran on the Sorelli Rocks off the coast of Africa and was wrecked with the loss of all but two officers and two men.

The combination of the sailing ship and the paddle steamer was seen for many years afterwards on the North American station, where the admiral flew his flag in a sailing line of battleship, but was always accompanied by a steamer which towed the flagship during calms and light head winds and which was towed by her during fresh and fair winds, so as to save her coal.[43] Practically all the paddle

[41] Life of Admiral Sir William Parker. Vol. III., p. 158.

[42] Memoirs and Correspondence of Admiral Sir Charles Napier. By Maj.-Gen, Napier. Vol. II.

[43] Life of Vice-Admiral Sir George Tryon. By Rear-Admiral C. C. P. Fitzgerald, 1898.

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wheel vessels we had saw active service during the Russian War and proved of great use. The screw, however, had already asserted its superiority; it was being universally adopted, and the result of the war was to cause the paddle wheel frigate and the old wooden line of battleship alike to be consigned to mere routine duties, if not to the scrap heap. As fighting ships, their day was done.

TABLE I.

Particulars of paddle despatch vessels, mail packets, tugs and sloops of less than 200 nominal horse power added to H.M. Navy during 1820-1850:

	Date.	Tons.	H.P.	Engine Makers.
" Acheron "	1838	760	160	Seaward
" Adder "	1827	241	100	B. & W.
" Advice "	1827	240	80	B. & W.
" African "	1828	295	90	Maudslay
" Alban "	1826	405	100	B. & W.
" Albert " I.	1841	456	70	
" Ariel "	(1837)	150	60	
" Asp "	1825	112	50	B. & W.
" Avon "	1825	361	170	B. & W.
" Beaver "		128	62	
" Blazer "	1834	527	120	Miller
" Bloodhound " I.	1845	370	150	Napier
" Boxer "	(1837)			
" Carron "	1827	494	120	
" Charon "	1831			
" Cherokee "	1842		20	
" Columbia "	1829	355	100	B. & W.
" Comet "	1822	238	80	B. & W.
" Confiance "	1827	294	100	Maudslay
" Cuckoo "	1831	234	100	B. & W.
" Dasher "	1837	260	100	Seaward
" Doterel "	1826	237	100	
" Dover " I.	1840	224	90	Fawcett
" Echo "	1827	294	140	Butterley
" Elfin "	1849	111	40	Rennie
" Experiment "	(1838)			
" Fearless "	1831	165	76	B. & W.
" Firebrand "	1831	494	140	Butterley
(Converted to " Black Eagle.")				

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	Date.	Tons.	H.P.	Engine Makers.
"Firequeen"	1845	312	120	Napier
"Flamer"	1831	496	120	
(Wrecked 22/11/50.)				
"Garland"	1845	292	120	
"Gleaner"	1833	351	130	B. & W.
"Jackal" I.	1845	340	150	Napier
"Jasper"	(1837)	387		
(Wrecked 1854.)				
"Kite"	1825	300	170	
"Lightning"	1823	296	100	Maudslay
"Lizard"	(1840)			
(Wrecked 24/7/43.)				
"Lizard" I.	1844	346	150	Napier
"Locust"	1840	284	100	Maudslay
"Lucifer"	1825	380	180	Maudslay
"Megæra"	1837	717	140	Seaward
(Wrecked 4/3/43.)				
"Messenger"	1830		120	Butterley
"Meteor"	1824	296	100	B. & W.
"Minos"	1840		40	
"Mohawk" I.	1841		60	
"Monkey"	1821	212	80	B. & W.
"Myrmidon"	1846	370	150	B. & W.
"Myrtle"	1829	116	50	B. & W.
"Onyx" I.	1843	292	120	
"Otter"	1831	237	120	B. & W.
"Pigmy"	1827	227	100	Fawcett
"Pike"	(1837)	111	50	
"Pluto"	1831	365	100	B. & W.
"Porcupine"	1844	380	132	Maudslay
"Princess Alice" I.	1844	270	120	Maudslay
"Prospero"	1829	249	144	Coates
"Recruit" I.	1846	425	160	
"Redwing"	1834	139	60	
"Rocket"			20	
"Shearwater"	1826	343	160	B. & W.
"Spitfire"	1832			
(Wrecked 19/4/42.)				

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	Date.	Tons.	H.P.	Engine Makers
" Spitfire "	1845	432	140	Butterley
" Sprightly "	1823	234	100	B. & W.
" Swallow "	1829	133	70	
" Tartarus "	1834	523	136	Miller
" Torch " I.	1845	340	120	Seaward
" Toronto "				
" Traveller "				
" Undine "			110	
" Urgent "	(1838)			
" Violet " I.	1843	292	120	
" Vivid "	1849	352	160	Penn
" Volcano "	1836	720	140	Seaward
" Vulcan "			140	
" Widgeon "	1837	225	90	Seaward
" Wildfire "	1826	186	76	B. & W.
" Zephyr "	1827	237	100	B. & W.

I=Iron. Dates in brackets thus (1837)=1st appearance in Navy List.
B. & W.=Boulton Watt & Co.

TABLE II.

Particulars of paddle wheel vessels in H.M. Navy of 200 nominal horse-power and over. 1832-1851.

Compiled mainly from the New Navy List of July, 1846, and Main & Brown's *Marine Steam Engine*, 4th Edition, 1860.

Steam vessels in 1846 were divided into six classes:—

Class A (1st Class Steam Frigate).—Tonnage, 1,444-1,847; n.h.p., 650-800. 360 men and upwards.

Class B (2nd Class Steam Frigate).—Tonnage, 1,200-1,300; n.h.p., 320-560. 175-200 men.

Class C (1st Class Steam Sloops).—Tonnage, 960-1,120; n.h.p., 280-420. 145 men.

Class D (2nd Class Steam Sloops).—Tonnage, 700-900; n.h.p., 140-240. 100 men.

Class E (1st Class Steam Gun Vessels).—Tonnage, 360-600; n.h.p., 100-230. 60 men.

Class F (2nd Class Steam Gun Vessels).—Includes all other of Her Majesty's steam vessels.

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Ship and Date.	Tons B.O.M.	Designer, Where Built.	N.H.P. I.H.P.	Maker and Type of Engine.	Cylinder. Stroke.	R.P.M	Diam. of Paddle Wheel.	Guns.
					ft. ins.		ft. ins.	
Alecto 1839	800	Symonds Chatham	200	Seaward Direct	53⅛ 4 6	14	21 11	5
Antelope I. 1846	649	Symonds Blackwall	260 646	Penn Oscillating	64 4 6	26	20 0	3
Ardent 1841	800	Symonds Chatham	200	Seaward Direct	53 4 6	18½	20 9	5
Argus 1849	975	Portsmouth	300 764	Penn Oscillating	64 6 0	16	23 5	6
Avenger 1845	1444	Symonds Devonport	650	Seaward				
Banshee 1847	670	Lang Rotherhithe	350	Penn Oscillating	72 5 6	30	25 0	3
Barracouta 1851	1048	Com. of Reference Pembroke	300 881	Miller and Ravenhill Direct	64 6 0	20		6
Basilisk 1848	980	Lang Woolwich	400 1033	Miller and Ravenhill Oscillating	74 6 0			6
Birkenhead I. 1845	1400	Laird Birkenhead	500	Laird				
Black Eagle 1831—1843	495	Converted by Lang from 'Firebrand I.'	260	Penn Oscillating	62¼ 4 6			
Bulldog 1845	1124	Symonds Chatham	500	Rennie Direct	— 5 6	16		6
Buzzard 1849	997	Surveyor's Dept. Pembroke	300 853	Miller and Ravenhill Oscillating	64 6 0			6
Caradoc I. 1847	660	Symonds Blackwall	350	Seaward Direct	74 6 0	28	25 6	2
Centaur 1845	1297	Symonds Portsmouth	540	Boulton and Watt Direct	85½ 6 0	18	28 0	6
Cormorant 1842	1057	Symonds Sheerness	280					
Cyclops 1837	1195	Symonds Pembroke	320	Seaward Direct	64 5 6	16	26 0	

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Ship and Date	Tons B.O.M.	Designer, Where Built.	N.H.P I.H.P.	Maker and Type of Engine.	Cylinder. Stroke. ft.	ins.	R.P.M	Diam. of Paddle Whee . ft.	ins.	Guns.
Dee 1832	704	Seppings and Lang Woolwich	200	Maudslay Side Lever	5	54 0	18	20	0	4
Devastation 1841	1058	Symonds Woolwich	400	Maudslay TwinCylinder	6	54 0	18			6
Dragon 1845	1295	Symonds Pembroke	560	Fairbairn Direct	5	88 9	17	27	6	6
Driver 1841	1060	Symonds Portsmouth	280	Seaward Direct	5	62 4	19	26	6	6
Firebrand 1843	1190	Symonds Portsmouth	410	Seaward Direct	5	75½ 9	18	26	6	6
Firefly 1832	550	Lang Woolwich	220	Maudslay Side Lever	5	55½ 0	21	20	0	4
Furious 1850	1286	Portsmouth	400	Miller and Ravenhill Oscillating	7	72 0	16	27	4	16
Fury 1845	1124	Symonds Sheerness	515	Rigby Direct	5	84 9	21	25	6	6
Geyser 1841	1060	Symonds Pembroke	280	Seaward Direct	5	63 3	18	26	6	6
Gladiator 1844	1210	Symonds Woolwich	430 943	Miller and Ravenhill Direct	5	78¾ 9	22	26	0	6
Gorgon 1837	1108	Symonds Pembroke	320	Seaward Direct	5	64 6	18	26	0	6
Growler 1841	1059	Symonds Chatham	280	Seaward Direct						
Harpy I. 1845	345	Symonds Blackwall	200 392	Napier Side Lever	4	49 0	23	16	0	1
Hecate 1839	817	Symonds Chatham	240	Scott and Sinclair Side Lever	5	60 9	16	25	0	6
Hecla 1839	817	Symonds Chatham	240	Scott and Sinclair Side Lever	5	60 9	18	24	0	6
Hermes 1835	830	Symonds Portsmouth	220	Maudslay Side Lever						
Hydra 1838	817	Symonds Chatham	240	Boulton & Watt Side Lever	5	56 0	17	24	0	6

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Ship and Date	Tons B.O.M.	Designer, Where Built	N.H.P. I.H.P.	Maker and Type of Engine.	Cylinder. Stroke.	R.P.M	Diam. of Paddle Wheel	Guns.
					ft. ins.		ft. ins.	
Inflexible 1846	1122	Symonds Pembroke	378	Fawcett Direct	72 5 9			6
Janus 1844	763	Dundonald Chatham	200	Dundonald Rotary				
Leopard 1850	1435	Fincham Deptford	560	Seaward Direct	91½ 6 8	17	32 0	18
Llewellyn 1847	650	Miller and Ravenhill Blackwall	350	Miller and Ravenhill	68 4 4	27	30 0	
Magicienne 1849	1255	Pembroke	400	Penn Oscillating	72 7 0		27 4	16
Medea 1833	836	Lang Woolwich	220	Maudslay Side Lever	54 5 0		24 0	
Medina 1840	889	Symonds Pembroke	312	Fawcett Side Lever	64 6 0	19	24 6	4
Medusa 1839	889	Symonds Pembroke	312	Fawcett Side Lever	64 6 0	19	24 6	4
Merlin 1837	889	Symonds Pembroke	312	Fawcett Side Lever	64 6 0	19	24 6	4
Oberon I. 1847	650	Symonds Deptford	260	Rennie Oscillating	61 5 0	21	21 0	3
Odin 1846	1326	Fincham Deptford	560	Fairbairn Direct	88½ 5 9	18	27 6	16
Penelope 1829-43	1616	Converted at Chatham	650	Seaward Direct	91½ 6 8	16	32 0	16
Phœnix 1832	802	Seppings Chatham	220	Maudslay Side Lever	55½ 5 0			6
Polyphemus 1840	800	Symonds Chatham	200	Seaward Direct				5
Prometheus 1839	800	Symonds Sheerness	200	Seaward Direct	53 4 6		22 6	5
Retribution 1844	1641	Symonds Chatham	800	Maudslay Twin Cylinder			25 0	28
Rhadamanthus 1832	813	Roberts Devonport	220	Maudslay Side Lever	55½ 5 0	18	20 0	4

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Ship and Date.	Tons B.O.M.	De igner. Where Built	N.H.P. I.H.P.	Maker and Type of Engine.	Cylinder. Stroke. ft.	Cylinder. Stroke. ins.	R.P.M	Diam. of Paddle Wheel. ft.	Diam. of Paddle Wheel. ins.	Guns.
Rosamond 1844	1059	Symonds Woolwich	280	Miller and Ravenhill Direct	5	65¼ 0	17	23	4	6
St. Columba 1847	719	Laird Birkenhead	350	Laird	5	70 6	25½	28	0	
Salamander 1832	818	Seaton Sheerness	220 506	Maudslay Side Lever	5	55½ 0	18	21	0	6
Samson 1844	1297	Symonds Woolwich	450	Rennie Direct	5	81 8	18	27	6	6
Scourge 1844	1124	Symonds Portsmouth	420	Maudslay Twin Cylinder	6	54 0	18	28	0	6
Sidon 1846	1328	Admiral Napier Deptford	560	Seaward Direct	6	86½ 0	16	27	6	22
Sphynx 1844	1058	Symonds Woolwich	500 1169	Penn Oscillating	6	82½ 0	17	28	0	6
Spiteful 1842	1050	Symonds Pembroke	280	Scott & Sinclair Side Lever	6	62 0	16	26	0	6
Stromboli 1839	970	Symonds Portsmouth	280	Napier Side Lever	6	63 0	16	25	0	6
Styx 1841	1050	Symonds Sheerness	280	Seaward Direct	5	63 3	16	24	0	6
Sydenham 1841	596	Purchased at Montreal	232							
Terrible 1845	1847	Lang Deptford	800 2059	Maudslay Twin Cylinder	8	72 0	14	34	0	21
Thunderbolt 1842	1055	Symonds Portsmouth	320	Napier Direct	5	67 0				
Tiger 1849	1221	Edye Chatham	400	Seaward						16
Trident 1846	848	Symonds Blackwall	350	Seaward Oscillating	5	71 0	24	17	0	6
Triton I. 1847	650	Symonds Blackwall	260	Boulton & Watt	4	64 6				3

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Ship and Date.	Tons. B.O.M.	Designer. Where Built.	N.H.P. I.H.P.	Maker and Type of Engine.	Cylinder. Stroke.	R.P.M	Diam. of Paddle Wheel.	Guns.
					ft. ins.		ft. ins.	
Valorous 1851	1258	Symonds Pembroke	400 1145	Penn	72 7 0			16
Vesuvius 1840	976	Symonds Sheerness	280	Napier Side Lever	63 6 0		25 0	6
Victoria and Albert 1843	1034	Symonds Pembroke	430	Maudslay Twin Cylinder	54 6 0	19	32 0	2
Virago 1842	1060	Symonds Chatham	300 546	Boulton & Watt Direct	66½ 5 0	17	24 9	6
Vixen 1840	1054	Symonds Pembroke	280	Seaward Direct	63 5 3	18	26 6	6
Vulture 1843	1190	Symonds Pembroke	470	Fairbairn Direct	80⅝ 5 9	19	25 0	6

The Author, in view of the fact that an abstract of his paper was in the hands of Members, said he would deal with his subject in the form of a lecture. This he did, illustrating it by means of some sixty lantern slides, among which were illustrations of ships, machinery and portraits of some of the prominent men connected with the early history of our steam navy.

DISCUSSION.

At the conclusion of the lecture, Mr. Worby Beaumont said he would like to move a vote of thanks to the author, who had given them a presentation of the remarkable story of his branch of the service in a remarkably interesting manner. Those who had had experience extending a long way back would appreciate the difficulties of these early engineers, lacking as they did, tools and materials. The story showed, too, how many desirable apparatus, such as the surface condenser and the evaporator, were invented, tried and given up under the conditions then prevailing. He asked if H.M.S. " Penelope," now at Harwich, was the paddle wheel vessel " Penelope " referred to in the paper.

Sir George Greenhill seconded. He referred to the little-known letter written by the poet Shelley, when in Sicily, where he describes his sensations on seeing a steamboat for the first time, and what he foresaw in the future. The vote of thanks was carried unanimously.

Eng. Rear-Admiral C. Rudd introduced himself as one of the old school of naval engineers, having started in Woolwich Dockyard in 1866. He was astounded

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at the amount of research that the author had put into his paper. Penn's oscillating engine had been his favourite, and he had always admired Penn's works at Greenwich. When compounding came in, existing engines were altered, *e.g.*, in the "Malabar" a high-pressure cylinder with return connecting rod was put in.

Mr. Forward said he could not discuss the paper in detail, but he might point out why indirect types of engine, *e.g.*, side-levers, remained so long in vogue, and that was because parallel or straight line linkages offered less friction than constrained guides as then fitted. He would like to refer to a letter he had recently come across in which Joshua Field advocated the training of naval engineers as early as 1830, and suggested a scheme to Sir Byam Martin of the Admiralty. (Mr. Forward read an extract from the letter.)

Eng. Capt. Ivor Roberts said that the section dealing with the training of the early engineers interested him most. This duty had always been neglected, while promises of better things were being held out. For 40 years executive officers had pleaded for better-trained engineer officers, and undoubtedly the Navy had suffered from lack of fully-trained men. It was not till 1862 that their training was placed on even a reasonable footing.

Mr. Lough. Pendred thought it was difficult to over-estimate the importance of the great advance made by Seaward with the "Gorgon" engine. It was direct acting, compact, and even anticipated Corliss in having four valves to each cylinder. He found it difficult to understand why the single eccentric gear persisted so long in marine engines, possibly because the number of reversals is small and because of its simplicity.

Mr. S. Russell said the Napiers were the great exponents of the side-lever engine. The author had not referred to the condenser situated in the paddle-box. The first compound naval engines were, he believed, the "Cricket," "Ant," and "Bee."

The President, in calling on the Author to reply, remarked that the Navy retained longer than anyone else the prejudice against high pressure steam.

The Author said the "Penelope," used as a depôt ship at Harwich, was a later ship of that name and not the paddle wheel frigate. As would be seen, when the whole was available, he had dealt in his paper with most of the points raised. The letter of Joshua Field was evidence of the efforts for reform in training engineers made outside the Navy; he would like a copy of it. Referring to this, he alluded to the "sulphur engineers," so called because, as boys, they were born in the old barque "Sulphur."

He had been fortunate in acquiring recently an album that belonged to the Engineers' Club at Portsmouth 20 years ago, containing photographs of a number of the older naval engineers. This he passed round for inspection.

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A Holograph Letter of Newcomen

communicated by

Conrad Matschoss, Dr. Ing. Ph.D.

(*Presented at Caxton Hall, Westminster, April 22nd,* 1922.)

Dr. Matchoss wrote that he had found this letter in a collection of documents presented to the Staatsbibliothek at Berlin in 1919, by Prof. Darmstaedter, who obtained it, as far as could be ascertained, prior to 1914, from an English second-hand bookseller. The letter is dated from Dartmouth, May 7th, 1725. A photograph of it accompanied the communication (*see* Pl. XX.), and was passed round.

The letter is addressed to Lord Chief Justice King, asking him to use his influence with Sir Matthew Decker to get an introduction in Holland for Newcomen's nephew, George, to obtain a patent there for a "new invented wind engine," *i.e.*, a windmill. This course is necessary because John Calley, who was charged with the mission, had died in Holland.

The Secretary confessed that he was so much impressed by the letter and its internal evidence, that he was prepared to accept it, although it might reasonably be doubted whether the composition of the letter was Newcomen's own; if so, we had here the only bit of Newcomen's handwriting extant, for hitherto, nothing had come to light.

First, as to the internal evidence: Peter King (b. 1669, d. 1734) was called to the Bar 8th June, 1698; Knighted 12th Sept., 1708; appointed Chief Justice of the Common Pleas 22nd Nov., 1714; created Lord King, Baron of Ockham in Surrey, 18th May, 1725; and Lord Chancellor 1st June following. The important fact, however, is that he was born at Exeter, where his father was a grocer and drysalter. Now, Newcomen (b. 1663) was only six years older than King, and as he was apprenticed in Exeter, it is not difficult to imagine how an acquaintanceship could spring up.

Matthew Decker (b. 1679, d. 1749) was born, probably in London, of Flemish parents who had fled thither in consequence of persecution. Young Decker started in business in 1702, and rapidly acquired wealth and importance. He was created a baronet 20th July, 1716, and in 1729 was Sheriff of Surrey. Obviously, by reason of his parentage, he was just the man through whom an introduction could be got to official circles in Holland.

Two new facts are disclosed in the letter: one is the death of Calley in Holland in 1725, instead of, as stated by Farey on the authority of Smeaton, in

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1717, at Whitkirk, in the parish of Austhorpe, near Leeds; the other is the invention of a windmill, apparently by Newcomen. A search has been instituted at the Record Office, but there is no mention of an application for a patent for a windmill in Newcomen's name.

A question that might be asked is why Newcomen should suggest his nephew for the mission, when his own sons, Thomas and Elias, were alive at the time.

In the discussion that ensued, Mr. Rhys Jenkins said he had made many attempts to find documentary matter in Newcomen's handwriting, but without success. In the absence of such handwriting, nothing conclusive could be said about the letter, but if Newcomen were such a ready writer as was the man who penned that letter, it was inconceivable to him that more correspondence should not have been preserved; it was a well-phrased and even a courtly letter.

Mr. Van Noorden said the general style and diction would place the letter at about the date when it purported to have been written. Mr. J. Macfarlan said the letter was undoubtedly in handwriting of the period.

Later, through Mr. A. F. Ravenshear (Member), the Secretary got into touch with Dr. Alingh Prins, of the Dutch Patent Office, who obligingly made a search there and found that the patent applied for was granted to Johan Brent and Johan Celly on Jan. 24th, 1726. The first-named can be no other than the John Brent, who obtained an English patent (Old Law, No. 471, A.D. 1724) for a "wind engine" for "occasioning motion to all sorts of millwork" whose "fanes move horizontally," the first one, it is believed, of this type. Dr. Prins further discovered that a John Kelly died at the Hague, March 9th, 1725, and there can be little doubt, in the light of the letter, that this Kelly is our Calley. Enquiries are still being prosecuted.—Ed.

[Transcript.]

Letter from Thomas Newcomen to Chief Justice King, May 7th, 1725. 1 sh., 4to. Preserved in the Staatsbibliothek, Berlin:

My Lord,—

It having pleased God in his Allwise Providence in some measure to disappoint us by the Death of Mr. John Calley, who was sent to Holland, in order to procure a Patent there for our New invented Wind Engine or Machine, I presume to give yor Lordship the trouble of these Lines, making my humble acknowledgements for the many Favours already received from you on that Occasion, particularly for yor kind recomendation of us to a Person of so much Honour and Benignity as Sr Matthew Deyker, who was pleased not only to favour

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us with his own Letter to a very worthy Gentleman, but also to procure another for us from the Dutch Ambassador to the Great Man at the Hague, which had all the good Effect that could well be desired, and the Affair was like soon to be brought to a good Issue, had it not been prevented by the Decease of our Agent there: But whilst I am acknowledging past Favours, the Circumstances of our Affair obliges me to inform yor Lordship that we stand in need of further Assistance; for designing not to lose the fair Prospect we have of Success in it, the Persons concerned have agreed to send my Nephew Mr George Newcomen to Holland, in order to perfect that which hath been so happily begun; and supposing it will be very proper, if not necessary, that he should also be well recommended on his going thither, as the Person who is to succeed Mr Calley in the Prosecution of that Affair; If yor Lordship is of the same Opinion, I humbly hope & desire you would be pleased to favour us with a fresh Recomendation to Sr Matthew, who I perswade my self will be so good as to renew his former Favours, and thereby compleat the Benefit he intended us, the full Effect of which hath hitherto been providentially prevented.

My Nephew, Mr. Elias Newcomen, who is to wait on yor Lordship with this will be ready to observe what Directions you shall be pleased to give him herein, and I shall allwayes be ready to acknowledge it as a great Adition to the many Obligations I already ly under, & with tenders of all due Respects am

My L^d

Yo^r Lordships very humble

and Obedient Servant

THO: NEWCOMEN.

Dartm^th. May 7th, 1725.

Addressed: To the Right Honourable the Lord Chief Justice King.

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A Note on Brunton's Steam Horse, 1813.

By Loughnan St. L. Pendred.

(*Read at Caxton Hall, Westminster, April 27th, 1922.*)

Although the author's intention is to do no more than discuss a single detail in the patent No. 3700, which William Brunton, then of Butterley Ironworks, Derbyshire, took out on May 22nd, 1813, for his well-known "steam horse" or "mechanical traveller," it may be convenient to recall a few of the facts which we know about that remarkable invention. The materials on which our knowledge is based are scanty. They consist of (a) a letter written by William Brunton to his brother; (b) the patent specification; and (c) contemporary notices in the press. The letter[1] now in the possession of the great-grandson of the inventor, who is with us to-night, is in effect a rough draft of the patent specification, but tells us even less than the latter about the design of the engine; apparently all details of it are lost. We know that one engine was made at Butterley, and that it was tried on the railway at the Company's Crick Lime Works[2] near by. The inventor stated that it performed very well, its speed being 2½ m.p.h. An engine, whether the same one or another is not known, was tried in 1813 on the Newbottle Colliery Railway, Durham. This method of haulage was found to be inconvenient and objectionable, so that it was abandoned.[3] It could not have been, therefore, the engine at this same colliery, whose boiler exploded on August 7th, 1815, killing eleven people outright and injuring 46 others[4], as has been too readily assumed.

It is the author's purpose, first to show that in one respect the patent drawing is so far defective that the machine shown could not have worked; secondly, to suggest that Brunton used, in a slightly modified form, that elegant parallel motion which many years later was known by the name of Scott Russell. It should, however, be said at once that Scott Russell in his "Steam Engine" admits that the geometry of the motion had long been known, though he states that he was the first to apply it in practice.

Let us turn now to the patent drawing (*see* Pl. XXI.) and consider one of the legs only. It will be observed that the upper member *eb* is jointed at its top end to the end of a lever hinged on a great bracket *s* attached to the top

[1]This was illustrated and described in "The Engineer," 1912, i., 164.
[2]Repertory of Arts, 1st Ser., XXIV, 65.
[3]Dunn, View of the Coal Trade of the North of England, 1844, 53.
[4]Gent. Mag., LXXXV., ii., 175.

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of the boiler and at its lower end to the head *b* of the piston rod. The lower part of the leg *ba*—the shin bone as it were—is hinged to the upper part and is inclined at 60 degrees to the ground, against which the foot presses in order to move the machine forward. Now, if we assume that the foot cannot slip backward, and that there is considerable resistance to the forward movement of the engine, then there is a large upward resultant pressure on the piston rod head. There is no provision of parallel motion or guides to take that pressure, and without them the gland could not have been kept tight, nor the bending of the rod have been prevented.

Observe now that at the centre point of the upper member, another rod half the length of that member is attached. There is a similar rod on the other leg, and the two lower ends of these rods are jointed together at *g*. No one seems to have asked what possible useful purpose these two rods could have served. As shown in the patent drawing, they are no more than useless complications. Shown as they are, they could not have made the design practicable; but let us add to the back of the boiler a strong bracket M (shown by thick dotted lines), and let us attach the lower ends of these mysterious rods to this bracket, and they at once perfect the design, for they provide the straight line motion for the piston rod head and take the upward thrust of the leg from the piston rod to the boiler itself. The linkage consisting of the upper member and the mysterious link firmly fixed at one end is Scott Russell's parallel motion, with one difference however. The end of the upper member should slide in a dead, straight path instead of swinging in an arc, but the arc is small and the radius is long, with the result that the departure of the path of the piston rod head from a straight line is negligible.

It is the belief of the author that William Brunton knew what he was doing, and that the links were put in for a definite and essential purpose. Was the bracket to which the lower ends of those links should be attached omitted purposely from the drawing in order to conceal an important part of the invention, or was it omitted accidentally?

The paper was illustrated by a model of Brunton's engine made by the author, and worked by means of a large bicycle pump, also by a diagram model of the linkwork.

Discussion.

Regarding the query in the last paragraph of the paper, Mr. A. J. Tennant said that it was within his experience that there was a disinclination on the part of some inventors to disclose everything in a patent specification, as in a chemical patent, for instance. This case, however, could not be of that kind, for an actual

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engine was constructed and hence the detail under discussion must have been disclosed. He would like to see the original patent drawing.

Mr. Brunton, great-grandson of the inventor, exhibited the original letter[5] of 1813, mentioned by Mr. Pendred, and said he had been interested, naturally, in the mechanical arrangement of this engine; he had even made a model, but had failed to get it to work because of the defect in the specification drawing. He was delighted with the model made by Mr. Pendred, and considered that his solution was correct. He had some documentary matter about the engine which he hoped to give to the Society some day.

Mr. Rhys Jenkins suggested that, in reproducing the drawing for the printed patent specification, the draughtsmen might have inadvertently left out this detail of the parallel motion.

Mr. J. Macfarlan wrote that he had examined the enrolled patent drawing (Petty Bag) at the Record Office, and the printed drawing was in exact agreement with it.

Mr. E. A. Forward wrote that since the reading of Mr. Pendred's paper, he had come across a photograph, said to have been taken about forty years ago, of a model of Brunton's engine, which appears to be very old, but nothing is known about it or whether it still exists. He could only suggest that it was the model that was exhibited at the Stephenson Centenary Exhibition at Newcastle in 1881. (*See* Pl. XXI.)[21]

The complete parallel motions are clearly shown, the fixed points being mounted on stiff brackets projecting from the end of the boiler, as the author suggested must have been the case. The cylinder, however, is inside the boiler, and not outside as that of the original is said to have been. How the two legs are connected is not clear, but there may even be two cylinders in this model. A knowledge of how the engine worked is here disclosed, and tends to support the view that the specification drawing is only inadvertently incomplete.

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[5]This letter has since been presented by Mr. Brunton to the Science Museum, South Kensington.—Ed.

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Notes on Heaton's Steam Carriage of 1830.

By Arthur Titley.

(*Read at Caxton Hall, Westminster, April 27th, 1922.*)

The MSS. I am now bringing to your notice have been lent to me by the grandsons of George Heaton, who, with his brothers John, William, and Reuben, were in partnership as engineers in Shadwell Street, Birmingham. They were the sons of Ralph Heaton, who originated the button-shank machine and other inventions. George Heaton is well known to have been the inventive brother of the four, although his name only appears in these papers as a partner. John and William were the scribes and business men of the concern, who signed documents and conducted correspondence.

They commenced building their first steam carriage in the early part of 1830. When they had completed it, in order to avoid publicity, they drew it with horses out of the town at night to a piece of common land at Moseley Wake Green, where they tried it. The next night after dark they raised steam and drove it back to Shadwell Street, to the surprise of the inhabitants. In working trim the engine weighed 50 cwt. It was intended to draw a cart behind it. The cylinders were originally of five inches diameter, but were replaced later by others of seven inches.

From a bill of John Maudsley, a Birmingham attorney, it appears that on July 6, 1830, he commenced the business of procuring an English and Scotch patent on their behalf. The date of the patent was October 6, and the number 6006. On October 15 a letter appeared in the *Mechanics' Magazine* over the initials "R.W.," describing the writer's having seen the engine drawing a press casting from Shadwell Street to a factory in Paradise Street. Its machinery could not be seen, but upon it was written "Heaton Brothers, Birmingham, Patent," and upon the front was the name "Enterprise."

An account of John Farey's shows that between January 15 and February 5, 1831, he was engaged in drawing up the specification for enrolment and in preparing the patent drawings from Heaton's originals. These were exhibited by members at the Summer Meeting of the Society in 1921. (*See* Plate XXII.) From an undated memorandum of expenses, which includes Farey's bill, it appears that William Heaton visited London to complete the patent business, and it was he who signed the specification for enrolment. A model of the engine had been made and sent to London where Farey inspected it. William Heaton when in London stayed at the Robin Hood Tavern in Holborn, kept by one Timothy Clancy, who afterwards appears as a shareholder in the company that was formed

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to put the engine on the road. Unfortunately during the year 1832, which must have been a period of interesting experiment, we have no evidence whatever among these MSS. It was a time of great activity in attempts at steam locomotion on common roads, and of public interest in them. Among the papers are correspondence with Farey, Alexander Gordon, the editors of *The Repertory of Patent Inventions,* and with J. Clinton Robertson, the editor of the *Mechanics' Magazine.* There are also circulars of the Institute of Locomotion, promoted by Gordon, and one referring to an engraving of Dr. Church's steam coach, published by Josiah Allen, a Birmingham printer.

On July 17, 1833, Heaton Brothers wrote to the *Mechanic's Magazine* an account of a run to Wolverhampton and back, the journey being enlivened by two break-downs on the way. On August 28, the engine made what appears to have been its second trip to Bromsgrove, over the Lickey Hills, with an incline of one in eight or nine, this route being chosen as the stiffest test that could be found in the neighbourhood of Birmingham. The Heatons described the trip in another letter to the magazine, accompanied by an illustration of the engine. A rough log of the run, evidently in George Heaton's hand, is among the papers.

A printed prospectus, dated September 16, 1833, with MS. amendments, shows that the company was formed about this date. It refers to trips of the steam carriage to Coventry, Bromsgrove, and Wolverhampton. By this document the Heatons were to build engines and the company was to run, hire, or sell them. A printed notice convening a meeting on October 3 to elect a committee of directors fixed the date of this event. The company is here referred to as "Heaton's Steam Carriage Company," but after this meeting the name was altered to "The Birmingham General Steam Carriage Company," as appears from a letter of November 25 from Wills, the solicitor acting for the shareholders. An agreement between the parties was drafted, but the Heatons and the shareholders were far from unanimous as to its terms, and it was not until January 17, 1834, that the document was signed and Heatons received the first payment of £1,000 of the £2,000 which was paid to them by the company under the agreement.

Shortly before the formation of the company, a coachmaker's bill commences, which gives details of repairs to the first steam carriage and of making of wheels, framing and body for a second one. J. Clinton Robertson had written introducing to the Heatons William Baddeley, a constant correspondent of the *Mechanics' Magazine,* who visited Birmingham and witnessed trials of both steam carriages. He describes the second one as a very beautiful machine; in trim, it weighed 77 cwt.

By the time the agreement with the company had been signed, the brothers had, from further experiments, come to the conclusion that there was a doubt of the engine being a success. This appears to have been known to the shareholders,

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and on February 5 Heatons received an order, signed by Henry Merry as chairman, ordering three steam carriages apparently for the purpose of putting the patentees to the test. On April 11 Heatons wrote to the company a candid confession of their inability to carry out the conditions of the contract, viz., that the engines should draw three tons at an average speed of ten miles per hour. The company, however, insisted on absolute fulfilment of the conditions. It has been stated[1] that Charles Shaw was the chairman, and that it was he who insisted on this. Among the (incomplete) list of shareholders in the company that is among the papers, Shaw's name does not appear, and Henry Merry was certainly chairman at this time and until the company ceased to exist. The company now ordered another three steam carriages, evidently to enable them to ground an action against the patentees for breach of contract.

The brothers now took Counsel's opinion on their position, and, acting on this, wrote offering to return £1,000 of the money they had received, and any amount over £1,000 that they might realise on the sale of the engines already built and the parts of those in hand, together with the patent rights. This was not accepted, and a counter proposal from the company that they should pay the company £1,366 to enable 20s. per share to be returned to the shareholders was agreed to by Heatons, as their cheque among the documents shows.

The advertisement of the engines for sale in *Aris's Gazette* brings the history of the Heaton's steam carriage to a close. From this it appears that two had actually been built, while two more were in course of construction.

MSS. Relating to Heaton's Steam Carriage, 1830.

(*Arranged in chronological order with interpolated references to letters bearing on the subject in the press.*[1])

1. A memorandum written in August, 1850, giving information as to the sequence of events.
2. 1830. July 6. Commencement of a bill of John Maudsley's, a Birmingham attorney, shows particulars of taking out Heaton's patent.
3. ,, Oct. 6. Copy of specification with drawings. (No. 6006.)
   ,, Oct. 15. Letter in *Mechanics' Magazine*, Vol. XIV., p. 184, over initials "R.W.," describing the writer having seen the steam carriage passing through the streets of Birmingham.
4. 1831. Jan. 25. A bill of John Farey's commencing at this date, refers to drafting specification for enrolment, and to making the patent drawings.
5. ,, A memorandum of expenses bearing no name or date. Evidently refers to William Heaton's visit to London about the completion of the patent.

[1]These documents have been presented to the City of Birmingham, and are now in the Reference Library there.

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6. 1831. Feb. 5. Duplicate of enrolled specification signed by William Heaton.
7. ,, March 22. Letter from the editors of the *Repertory of Patent Inventions* asking for information about the steam carriage.
   ,, March 22. Notice of the patent in *Mechanics' Magazine*, Vol. XV., p. 245.
   1832. N.B.—*No MSS. in this year.*
8. 1833. July 9. Letter from John Farey to Heaton Brothers.
9. ,, July 12. Letter from Alexander Gordon to Heaton Brothers.
10. ,, July 13. Letter from J. Clinton Robertson, Editor of *Mech. Mag.*
    ,, July 17. Letter from Heaton Brothers to *Mech. Mag.*, Vol. XIX., p. 272, describing trip to Wolverhampton.
11. 1833. July 25. Letter from J. Clinton Robertson introducing William Baddeley to Heaton Brothers.
12. ,, August 13. A bill from Brown, a coachbuilder, commences. Gives details of repairs to first steam carriage and new parts for a second one.
    ,, August 13. Letter from William Baddeley to *Mech. Mag.*, Vol. XIX., p. 350, describes trials of steam carriage round Birmingham.
13. ,, August 28. Rough draft of letter from Heaton Brothers to *Mech. Mag.*, Vol. XIX., p. 418, with illustration of engine. Refers to run to Bromsgrove.
14. 1833. Rough draft of log of run to Bromsgrove, probably in George Heaton's handwriting.
15. ,, Sept. 16. Printed prospectus of Heaton's Steam Carriage Company with MS. amendments. Also four rough drafts of same.
16. ,, Sept. 21. Letter from Horsfall, a Coventry innkeeper, referring to proposed running of steam carriages to that town.
17. ,, Sept. 21. Letter from Timothy Clancy, of the Robin Hood Tavern, Holborn, applying for shares in the company.
18. ,, Sept. 23. Account for advertisement of steam carriage in *Aris's Gazette.*
19. ,, Sept. 23. Ditto in the *Birmingham Journal.*
20. ,, Oct. 3. Letter from Alexander Gordon to Heaton Brothers.
21. ,, Oct. 3. Notice of first meeting of the company sent to Alfred Heaton.
    ,, Oct. 19. Notice of first meeting in *Mech. Mag.*, Vol. XX., p. 47.
22. ,, Nov. 25. Letter from Fred. Wills, solicitor to the company, referring to draft agreement.
23. ,, Letter from Henry Merry (no date), referring to same.
24. ,, Estimate of cost of running steam carriage to London appears to be of about this date.
    1834. Feb. 4. Letter from company (Henry Merry, chairman), ordering three steam carriages. (Copy contained in No. 29.)

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25. 1834. March 27. Fred Wills's bill for copy of agreement paid.
26. „ April 11. Draft of letter from Heaton Brothers to the company saying that steam carriage is not successful.
„ April 19. Letter from the company with copy of resolution. (Copy contained in No. 29.)
„ April 28. Letter from W. Baddeley to *Mech. Mag.*, Vol. XXI., p. 79.
27. „ May 23. Letter from John Harwood, shareholder.
28. „ June 23. Letter from the company ordering three more steam carriages.
29. „ July 28. "Case," with Counsel's (B. Peacock) opinion.
30. „ July 29. Draft of letter from Heaton Brothers making offer.
31. „ Statement of expense Heatons had been put to appears to be about this date.
32. „ Sept. 2. Company's letter with counter proposal.
33. „ Sept. 26. Heaton Brothers' cheque.
34. „ Nov. 3. Account for advertisement of steam carriage for sale, in *Aris's Gazette.*
35. 1835. Feb. 9. Bill of Unett & Son, Heaton's solicitors, paid.
36. Three draft descriptions of steam carriage. One written in book is probably in George Heaton's hand.
37. MS. copy of enrolled specification.
38. MS. list of shareholders written in book.
39. Blank share application form of "Heaton's Steam Carriage Company," shows that they had proceeded so far before the election of directors on Oct. 3, 1833.
40. Circular of Institute of Locomotion.
41. Ditto of Josiah Allen's engraving of Dr. Church's steam carriage.
42. Prospectus of company under Witty's patent.
43. Fragment of prospectus of Dr. Church's company.
44. Two original drawings of Heaton's Steam Carriage. (*See* Pl. XXII. for one of these.)

Discussion.

Mr. Dendy Marshall mentioned that in April, 1834, the Heaton Steam Carriage shares were at a premium of £10.[2] In May of the same year[3] a letter from Baddeley appeared announcing the failure of the carriage to pay expenses, and its consequent withdrawal, commenting favourably on Messrs. Heaton's conduct in the matter.

[2]Mech. Mag., XXI., 48.
[3]*Ibid.*, p. 79.

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Colonel Foster enquired if there were any record of a trip to Coventry. He believed that the Heatons were received there so badly that they had to defend themselves with the fire-irons.

Mr. D. S. Levien wrote with regard to the Institute of Locomotion that the *Journal of Steam Transport and Husbandry,*" Dec., 1833, published under the patronage of the Institute, contains an eight-page report of the proceedings of the "National Institute of Locomotion," with a list of quite a strong provisional Committee, including about thirty members of Parliament, among whom was Sir George Cayley. The Institution seems to have started with the title: "A Society for Promoting the Application of Steam to General Transport and Agricultural Purposes."[4]

[4]Gordon—Treatise upon Elemental Locomotion, 2nd ed., Appendix A.

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Gurney's Railway Locomotives, 1830.

By E. A. Forward.

(Read at Caxton Hall, Westminster, April 27th, 1922.)

Although Sir Goldsworthy Gurney's work in connection with steam carriages on common roads is well-known, it is less well-known that some of his steam carriages were adapted for railway use; this account of them may, therefore, be of interest.

The first mention of such engines occurs in Gurney's evidence before the Select Committee of the House of Commons on Steam Carriages in 1831, when he referred to some experiments that he had made in Wales with Mr. Crawshay, of Cyfarthfa, which showed that on a railway a steam carriage could draw thirty times its own weight.

Alexander Gordon, who was also a witness before the Committee, noted this evidence, and endeavoured to obtain particulars of these experiments. He found, and printed in his *Treatise on Elemental Locomotion*, 1832, a letter dealing with them written by Wm. Crawshay, Jnr., on March 18th, 1830, and published in the *Cambrian* newspaper. It appears that Crawshay had been in London three weeks earlier, and had, with considerable difficulty, persuaded Gurney to bring one of his steam carriages, built for drawing coaches on turnpike roads, to try its powers on their new railroad on Hirwain Common.[1] The engine was brought from London to Cyfarthfa by a pair of horses, on its ordinary wheels, and was there fitted with cast-iron wheels and otherwise adapted to the railroad, of which a small piece, similar to that at Hirwain, was laid down for the purpose. The engine, with water and fuel, weighed 30 cwt., two-thirds of which was on the hind wheels. By it was drawn a carriage weighing 25cwt., on which was a load of 23 tons[2] of pig-iron.

On the following day the engine was sent to Hirwain, and placed upon the railroad, which was dead level 3 miles long. Five carriages containing pig-iron, one with seats and upwards of 100 persons, making a total load of 20.4 tons, was attached to the engine. Crawshay himself laid and lit the fire, and steam was raised in 4 min. 50 sec. after he had applied the light. The engine started off with its load, and covered the three miles in 39 min., returning in 32 min. In a

[1]Hirwain is about 5 miles west of Merthyr Tydvil.

[2]This is not an error, see Gordon's "Treatise," page 71. It was a special experiment; long square iron pigs purposely cast were loaded on a single truck and drawn a short distance by the engine on a specially strengthened piece of track.

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subsequent experiment, the engine drew 21.5 tons over the same length of line in 18 min. The engine was then loaded up to 40 cwt., and drew 33.9 tons at a speed of 2.5 miles an hour. "In all cases Mr. Gurney's engine has drawn from 15 to 16½ times its own weight, upon a level road, and has produced more than sufficient steam for the purpose."

On Nov. 21st of the same year, Crawshay wrote to Simon Goodrich upon the subject of the performance of Gurney's boilers, which the latter had tested previously. He says:—

> "I have had Mr. Gurney's 2 engines here at work about 14 days, and I find every expectation I entertained of the superiority of his boiler is more than realised as far as the production of steam. The engines are drawing, at 3 to 4 miles an hour, 30 to 35 times their own weight, but whether the rough state of the wheels, or roads, assists this great superiority at present, we shall better know in another 14 days. However, the engines are quite what I expected and, with 25 tons after them, they have travelled 8 miles an hour, the whole weight of the machine being 34 cwt. only, 25 cwt. bearing on the working wheels."

Later, on Feb. 23, 1832, Wm. Crawshay made a report on the engines to Sir Charles Dance, which is also quoted by Gordon. Crawshay says:—

> "The favourable opinion entertained by my engineer and myself of the tubular boiler (Mr. Gurney's) over every other we have yet seen, not only remains unshaken, but is strengthened and confirmed by eighteen months' constant use, and observation of it on our own road. The ease and economy of first construction; the facility of repair when required; the extreme lightness; the great capacity for raising steam; and the perfect freedom from danger of the tubular boiler, all render it, in our opinions, pre-eminently adapted to locomotive engines, and I hope in the course of a few months to apply it to engines and carriages suited to railroads and heavy work so successfully, as to render the advantage of steam-power over that of horses still greater than it now is. . . . I beg to state to you, that in the past 12 months, between the first of Jan., 1831, and the 1st of Jan., 1832, the locomotive engine which I bought of Mr. Gurney, weighing only 35 cwt., including everything whatever belonging to it, with water and fuel in a working state, conveyed 42,300 tons of coal, iron-stone and iron, exclusive of the carriages on which they were drawn, the distance of 2½ miles upon our railroad at Hirwain, in journeys of 20 to 30 tons, as suited our convenience; during which time the entire consumption of coal was 299 tons, costing £44 17s. The total expenses amounted to £112 9s., or less than one farthing per ton per mile.

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"You are sufficiently acquainted with the experience of horse-power to render any comparison on my part unnecessary; but from the observation I have been able to make, in contrasting horse-power with that of steam, on the same road, I should certainly consider that the average of horse-power, compared with that of steam, under the most improved application, is in point of expense as 20 or even 30 to 1; I consider that the unprecedented depression of the iron trade, and the late disturbances in South Wales, have much impeded the further introduction, use, and improvement of locomotive engines in this part of the country, and it is a matter much to be regretted that more talent, competition and energy are not at this moment excited everywhere in the furtherance of so great a national advantage, as the substitution of the cheaper power of steam, wherever practicable, for that of horses.

(Signed) WILLIAM CRAWSHAY."

This appears to be all that is known of Gurney's rail locomotives, and it is curious that after their initial success no mention of them, as far as the writer is aware, should have been made elsewhere.

DISCUSSION.

Mr. Worby Beaumont said he had discussed Gurney's work on steam traction on common roads in his Cantor Lectures in 1895, but he was not aware that so much had been done by Gurney in rail traction. It was curious that no further progress should have been made in that direction, where there were no limitations, as there were on roads.

Mr. Rhys Jenkins said the probable explanation was that a great depression in trade occurred about 1830, with the result that the Crawshays gave up the Hirwain works, and eventually sold them to another firm. Meantime, another and better type of locomotive had been developed. Gurney's engine worked for about two years, but he had failed to find any local tradition about it.

Mr. G. F. Tyas enquired if the Neath Abbey Iron Co. did not begin making locomotives soon after 1830; Mr. Jenkins said that was the case.

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The Newcomen Society

FOR THE STUDY OF THE HISTORY OF ENGINEERING AND TECHNOLOGY.

Summer Meeting in London

JUNE 1ST AND 2ND, 1922.

FIRST DAY'S PROCEEDINGS.

Members and guests met on Thursday morning, June 1st, at the Science Museum, South Kensington, where they were received in the unfinished New Buildings by the Director, Col. H. G. Lyons, F.R.S., who, in a short speech, explained the work that was in progress, and suggested that Members could use their personal influence in furthering the interests of the Museum.

A tour of the Mechanical and Marine Engineering Collection was then undertaken, under the guidance of Mr. E. A. Forward and the Secretary, beginning with an actual Newcomen engine recently re-erected in the New Building, and taking in the Watt engine and models, early locomotives, and marine engines. Only a rapid survey was possible in the limited time available.

Luncheon was partaken of at the Victoria and Albert Refreshment Room, and a move was then made for Westminster, where a visit to the restoration work on the roof of Westminster Hall had been arranged. A memorandum on the subject was issued to those taking part. Members were met in New Palace Yard by Sir Frank Baines, M.V.O., Director of Works, who took the party into one of the Committee Rooms of the House, where he had arranged an exhibit of specimens and coloured drawings recording the state of decay in which different parts of the roof was found. In a lucid and succinct manner he traced the history of the roof[1] from its construction by Hugh Herland, "Keeper of the King's Carpentry Works," in 1394-9, and described the extensive ravages in the timbers caused by the larva of the death watch beetle, and detailed the steps being taken to remedy this. The party then passed into the Hall itself, where he showed the steel reinforcing trusses, and how they were inserted with such cunning as to be almost invisible. An ascent by ladders and staging into the forest of timbers on the roof enabled Members to see the ravages of the larvae and judge the magnitude of the work.

It was with great reluctance that the Members tore themselves away, but a move had to be made to the Guildhall, for a visit to the Horological Collections

[1]For a discussion of the principles upon which hammer-beam roofs were designed, and a description of this particular Roof, see "Engineer," CXXXII. 697.—ED.

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of the Worshipful Company of Clockmakers had been arranged. The party was heartily welcomed by the Deputy Master of the Company, Mr. T. A. Bullock. The Librarian, Mr. B. Kettle, introduced Mr. Inkerman Rogers, F.B.H.I., F.G.S., who delivered an address on the progress of Horology, illustrated by objects in the Collections[2] pointed out by Mr. Alfred J. Barnsdale. The party was augmented by a number of ex-Service men from the Farringdon Road Government Training Centre, under Mr. Rogers. The entire party was entertained to tea by kind invitation of the Master and Assistants of the Company.

Members dined together in the evening at the Engineers' Club, Coventry Street. One loyal toast was given, and to everyone's relief no speeches were made.

Second Day's Proceedings.

The meeting took place at the Institution of Mechanical Engineers, Storey's Gate, where a motor char-a-banc was in waiting to take Members and guests to the Rotunda, Woolwich, containing the Collection belonging to the Royal Artillery Institution. The route followed was through Camberwell, Deptford, Shooter's Hill, and Woolwich Common. Arrived at their destination, the party was met by the officer in charge. The ordnance outside was first inspected, a Turkish bronze piece with screwed breech attracting most attention. Inside, the chief steps in the development of guns and small arms, from a breech-loading gun with carriage recovered from the wreck of the "Mary Rose," 1545, to the present day, were rapidly followed; here the knowledge of two of the Members, Sir George Greenhill, for ordnance, and Mr. W. W. Greener, for small arms, was invaluable.

A short run brought the party to the Ship Hotel, Greenwich, where luncheon was partaken of in a room overlooking the Thames.

The afternoon visit was to the Naval Museum, by special arrangement with the Curator, Mr. J. T. Berry, R.N. The original block-making models of Brunel and Maudslay, and the series of early warship models attracted much notice. By kind permission of the Chief Inspector of Police, a restful half-hour was spent in the Painted Hall (not open to the public on this day), and a visit was paid to the crypt—all that is left of the Greenwich Palace of the Tudors—before resuming the motor journey.

A halt was made at the Deptford Pumping Station of the Metropolitan Water Board, where, by kind invitation and under the personal guidance of the District Engineer, Mr. T. Melhuish, M.I.Mech.E., the Boulton & Watt pumping engines of date 1812 and 1824 respectively, together with the boilers, soon to be scrapped, were inspected. A memorandum giving particulars of the plant was in the hands of visitors.

The journey to Westminster was then resumed, and on arrival the party dispersed, tired, but satisfied with the success of the Meeting.

[2]See Catalogue of the Museum of the Worshipful Company of Clockmakers of London, 2nd Edition, 1902.

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Notes and Communications.

An 18th Century Engineer's Sketch Book.

By H. W. Dickinson.

At the Society's Summer Meeting in 1921 at Birmingham, there was exhibited[1] by Sir Gerald Chadwyck-Healey, Bart., an old sketch book that deserves further notice on account of the use that might possibly be made of its contents by the future historian.

From internal evidence the writer was able to identify the book as being that got together in the 18th century by the industry of William Reynolds (b. 1758, d. 1803), of Ketley Ironworks, Shropshire, son of Richard Reynolds, of Coalbrookdale. This William occupied a responsible position, and was a man of an inventive turn of mind, who is remembered as having collaborated with Thomas Telford in introducing cast iron troughing for canal aqueducts and as having suggested and brought into use in 1788 at Coalport and elsewhere the inclined plane instead of locks for use on canals for raising and lowering barges.

After several vicissitudes the book passed into the possession of John Randall of Madeley, a local historian and writer of note, who published a description[2] of it and a partial list of the contents. He stated that he had also in his possession, from the same source, " 30 vols. fol. MS., beautifully written and containing suggestions, inventions and drawings, but chiefly copies from the transactions of the Royal Society and other sources. Doubtless if these could be found they would throw further light on the contents of the book.

Soon after 1879 the book disappeared unaccountably, but was unearthed by one of the Members of the Society in the library of Sir Gerald Chadwyck-Healey. We are pleased to state that the book has now been presented by him to the nation, and can be consulted in the Library of the Science Museum, South Kensington.

It may be said at once that there is nothing in the volume of outstanding importance, but its range is a wide one; designs of steam engines, particularly those intended to give rotative motion for winding from pits, etc.; manufacture of iron; methods of winning coal; excavating plant for canals; bridges and viaducts; in fact, all the engineering questions in which Reynolds was interested are displayed. The information thus supplied on many minor aspects of

[1] "Trans.," I. 75.
[2] Madeley Herald and Borough of Wenlock Advertiser, July 19th, 1879.

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engineering in an obscure period of its history may fill a gap here and there; hence no apology is needed for giving the subjoined list[3] of the drawings with brief annotations where such are necessary.

CONTENTS.

Where the scale or date is not given, but is deduced from internal evidence, it is placed within brackets.

1. Ink drawing; elevation and cross section; scale 1.96. "Duncombe's idea of stone aqueduct for Pont-y-Cysulte, April, 1794." Pont-y-Cysylltau Aqueduct, on the Ellesmere Canal, was built of cast iron troughing by Thos. Telford 1795 to 1803.
2. Copperplate engraving; (scale 1.48). "Multiplying Wheel Bucket Engine," invented by George Gerves in 1725 for raising water, with separate printed "Explanation." Both draft and explanation prepared by Henry Beighton, F.R.S., 1727. A bucket filled with water raises a smaller bucket through three times the height that the larger descends.
3. Pencil sketch; sectional elevation; no scale. "Sadler's idea of an engine brought by him when he came from Bristol, 1794." This was not patented. The patent taken out by James Sadler in A.D. 1791, No. 1812, was for an Æolipile with a condenser.
4. Ink sketch; front and side elvation; no scale. "Sadler's rotative motion," with crank, for winding engine. May 30, 1793.
5. Ink sketch; sectional elevation; no scale. "Small engine as it worked on the hill at the Dale, made by James Sadler, 1792." "The Dale" is Coalbrookdale.
6. Pencil sketch; sectional elevation; not to scale. "S. Venables's drawg. of Sadler's engine as it stood when T. Griffiths was puttg. it up at the Bank." Sept., "1793."
7. Ink sketch; sectional elevation; no scale. "J. Sadler's new engine sent by Dr. Beddoes. May, 1793," with lettered description.
8. Ink drawings; scale 1.4. Details of parts of No. 7. On the back is "Drawings of an engine by Jas. Sadler before he went to London with Dr. Beddoes to which he wants to make additions, not being complete."
9. Ink drawing; no scale. Details of "engine for J. Sadler, but which was never completed, 1794."
10. Ink sketch, probably full size. "Joint for cast iron plates by Mr. Betancourt. Jan., 1796."
11. Pen-and-ink sketch with description. "An account of Mr. Thos. Savory's

[3] We are indebted to the Director of the Science Museum for permission to use this officially compiled list.—ED.

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engine for raising water by the help of fire," as shown to the Royal Society. June 14th, 1699. Taken from Phil. Trans., No. 253, p. 228.

12. Ink drawing; sectional elevation and details; scale 1.24. "Watt's steam wheel." No date.

13. Copperplate engraving; scale 1.250. John Carne's patent [No. 1,440, A.D. 1784] machine for removing earth, with printed description of savings made with it at Gloucester Canal, Dec., 1793. The machine is a transporter worked by a horse gear.

14. Copperplate engraving, "William Bingley's new invented iron chain to take the place of ropes," with letterpress description. Dated August, 1795. The link is of round iron, ends interlocked and folded, not welded.

15. Copperplate engraving; elevation and plan. "Horizontal windmill [for raising water.] Chev. de Betancourt, 1784." A pencil note states "for the 2d vol. of the Architecture hydraulique by Mr. Prony." It is, however, not to be found in that work.

16 and 17. Wash drawings; plan and elevation respectively; no scale. Horizontal water wheel or turbine for winding from mines.

18. Wash drawing; no scale. "Glazebrook's scheme to effect a perpendicular motion, 1795." Simply Watt's parallel motion. The lever is an auxiliary for driving a crank, etc.

19. Coloured drawing; sectional elevation; scale 1.12. "Adam Heslop's engine to work without a beam." Drawn by S. Venables. This was a form of atmospheric engine with two cylinders. (See Heslop's Pat. Spec., A.D. 1790, No. 1,760.

20. Perspective coloured drawing; no scale. Two open-topped cylinders with separate condensers, the pistons connected by a chain over a wheel which gives motion to a stand of partly grooved rolls. No date. Probably Robert Cameron's patent engine and Wilkinson's design of rolls.

21. Wash drawing; elevation and plan; (scale, say, 1.96). Horse-drawn hoist for raising earth (*e.g.*, canal excavation) to a gantry with run-off for the spoil. No date, but watermark 1794.

22. Ink drawing; sectional elevation; no scale. "R. Speed's first copy of Venables's drawing of engine, June 1st, 1796." Apparently Sadler's engine with boiler, arranged for winding from a mine.

23. Coloured drawing; sectional elevation; scale 1.12. Appears to be atmospheric return connecting rod engine geared for winding from mines. By S. Venables, dated April 16th, 1795. Part of Set 24 and 25.

24. Coloured drawing; plan; scale 1.12. Appears to be atmospheric return connecting rod engine geared for winding from mines. By S. Venables, dated April 16th, 1795. Part of Set 23 and 25.

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25. Coloured drawing; side elevation; scale 1.12. Appears to be atmospheric return connecting rod engine geared for winding from mines, by S. Venables, dated April 16th, 1795. Part of Set 23 and 24.
26. Coloured drawing; sectional elevation; no scale. Apparently Watt type single acting engine with connecting rod for winding. No date.
27. Coloured drawing; side elevation and plan; scale 1.24. "The engine without a beam erected at Wombridge, Dec. 5, 1794." This is an engine similar to 23-25 *ante*.
28. Coloured drawing; sectional elevation; no scale. Apparently an atmospheric beam engine with crank, connecting rod and flywheel. No date.

29 and 30. Shaded coloured drawings, duplicates; scale 1.12. "Details de la machine pour transporter les terres"; apparently a suspension gravity railway. No date. (For general drawing see Nos. 104 and 105.)

31. Coloured drawing; sectional elevation and plan; scale 1.36. Apparently an engine of the Watt double acting type, with wagon boiler. No date.
32. Coloured drawing; elevation; no scale. "Lower working gear" apparently of Watt type double acting engine. No date.
33. Wash drawing front elevation; no scale. Apparently of atmospheric beam engine with crank, connecting rod, flywheel and gearing. No date.
34. Coloured drawing; side and end elevations; scale 1.24. "General section of an engine for winding coals," dated July 27, 1793. Apparently a Heslop engine.
35. Coloured drawing; end elevation; scale 1.36. "Horsehay's forge engine. Feb. 21, 1793." Shows connecting rod with sun and planet gear working a tilt hammer.
36. Coloured drawing; sectional elevation; scale 1.48. "Hollins Wood Blast Engine," dated Sept. 12, 1793, by William Minor. Shows atmospheric beam engine working blowing cylinder communicating with water-sealed blast regulator and shows section of blast furnace. (Compare No. 41 with this.)
37. Coloured drawings; sectional elevation; scale 1.12. "The engine for winding coals." No date. Engine is of the double-acting Watt type with crank and connecting rod. Nos. 70 and 101 are copies of this.
38. Pencil drawing partly inked in; no scale. Exterior of canal incline winding engine and house. No date. (Compare Nos. 48 and 98 with this.)
39. Coloured drawings; sectional elevation; no scale. Apparently a Heslop engine for rotative motion. By Samuel Venables, dated September 1st, 1793.
40. Ink drawing; sectional elevation and plan of engine and boiler; scale 1.24. "W. Reynolds's idea of the application of Sadler's engine to a rotative motion, the lower cylinder communicating with the boiler; this method is

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applicable to rowing boats with circular oars, 1795." By S. Venables, dated February 13th, 1796.

41. Coloured drawing; no scale or date; blast furnace blowing plant. Practically a duplicate of No. 36.
42. Pencil perspective drawing; no size. Atmospheric engine pumping plant for colliery. No date.
43. Wash drawing. No scale or title. Pumps. No date.
44. Coloured drawing; plan and elevation; no scale. Winding gear used on the Ketley Canal inclined plane.
45. Pen-and-ink sketch; vertical section. No scale. Appears to be a Savery engine.
46 Ink drawing; sectional elevation and plan; scale 1.12. "Richard Bank's idea of a boiler, 1796." Appears to be superimposed cheese-shaped vessels.
47. Ink drawing; end elevation; scale 1.12. Portable engine for winding coals, 1792. Part of the set Nos. 49, 50 and 76.
48. Pen-and-ink perspective sketch; elevation; no size. Exterior of canal incline winding engine. No date. (Compare Nos. 38 and 98 with this.)
49. Ink drawing; front and side view; scale 1.4. "Working gear," obviously for the portable winding engine, 1792. Part of the set Nos. 47, 50 and 76.
50. Ink drawing; front elevation; scale 1.12. Portable "engine for winding coals," with connecting rod, sun and planet motion and flywheel, "90 strokes per minute," dated November, 1792. Part of the set Nos. 47, 49 and 76.
51. Pen-and-ink sketch; elevation (scale may be 1.48). No date. Appears to be a Savery engine.
52. Pencil sketch; elevation; no scale. "Mr. Fulton's idea of moving boats [*i.e.*, on canals.] April, 1795." His patent was No. 1,988, A.D. 1794.
53. Pencil drawing; elevation; no scale or date. Brake drum and winding gear for inclined plane.
54. Pencil perspective drawing and details; no scale. Coal screen. No date.
55. Ink drawing; section; no scale. Loose bevel wheel gear. No date.
56. Pen perspective sketch; no size. Atmospheric pumping engine. No date.
57. Pen perspective sketch; no size. Blast furnace plant. No date.
58. Pencil perspective drawing; no size. Winding engine plant. No date. Same engine as 61.
59. Pen perspective drawing; no size. Winding engine plant. No date.
60. Pencil perspective drawing partially inked; no size. Beam pumping engine plant. No date.
61. Pencil perspective drawing partially inked in; no size. Winding engine plant. No date. Same engine as 58.
62. Pen perspective sketch; no size. Winding engine plant. No date.

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63. Pen perspective sketch; no size. Winding engine plant, another view. No date.
64. Pencil perspective sketch; no size. Pumping engine plant. No date.
65. Pencil perspective sketch; no size. Winding engine plant. No date.
66. Pencil sketch; section and part plan; no scale. Apparently return connecting rod engine plant. No date.
67. Pencil perspective sketch; no size. Apparently winding gear with brake drum. No date.
68. Pen-and-ink sketch; not to scale. Apparently a Savery engine. No date. (Compare with No. 83.)
69. Ink drawing; plan; no scale. "Mode of getting the coal near Brierley Hill, by T. Price. May, 1803."
70. Ink drawing; sectional elevation; no scale. Watt type rotative beam engine with crank and connecting rod. A duplicate of Nos. 37 and 101.
71. Pencil sketch; section; not to scale. "Hornblower's air pump," dated 1793.
72. Ink drawing; end and side elevation; scale 1.24. "Jinney for conveying wheeled corves down descents." No date.
73. Explanatory diagram; scale 1.24. "Calculation of the power of Mr. Anstice's rotative engine by D. Rose. March 17th, 1799."
74. Ink drawing plan; no scale. Mode of getting coal near a roll. T. Price. March, 1803."
75. Wash drawing; elevation; no scale. Steam cylinder marked "Thos. Sadler, 1793."
76. Ink drawing; plan; scale 1.12. Portable engine for winding coals. 1792. Part of the set Nos. 47, 49 and 50.
77. Rough pencil sketches; not to scale. Horse gear, bridge, etc. No date.
78. Rough pencil sketches; not to scale. "Corn Market Roof at Paris" (on de Lolme's principle): "Brick machinery, 1794." Lord Dundonald's (?). No date.
79. Rough pencil sketches; no scale. Ships, etc. No date.
80. Pencil sketch; elevation. "Elephant's jaw for extracting [boring] rods when broken, made by Thos. Price of Oaken Gates. March, 1803."
81. Pencil sketch; elevation and plan; no scale. "1st sketch of River Mill by W. R. (*i.e.*, William Reynolds). Jan., 1796. Improved by de Betancourt. Obviously the rough sketches for the finished drawings 99, 100, 102 and 103 below.
82. Ink sketch; vertical section; no scale. "New method of boreing used by T. Price at the Bumble Hole Colly, near the Level." March, 1803. Shows boring with rods.

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83. Pen drawing; elevation; details to scale 1.7. Apparently a Savery type engine. No date. Resembles No. 68.
84. Pen drawing; outline elevation; not to scale. Obviously Coalbrookdale Iron Bridge. No date.
85. Pen drawing; plan; no scale. "Mode of getting the 10 yard [coal] near Gospel Oak, by T. Price." Date torn off, but probably 1803.
86. Pen sketch; no scale. Unspecified. No date.
87. Coloured drawing; no scale. Obviously a Savery engine. No date.
88. Pencil drawing; no scale. (?) Tilt hammer heads. No date.
89. Rough pencil sketches; no scale. "Sundry ideas, 1793." Roller bearing, etc.
90. Pencil sketch; no scale. "Hornblower's air pump." No date.
91. Pen-and-ink sketch; sectional elevation. No scale. Blakey's fire engine, with legend (Pat. No. 848, A.D. 1766), intended for raising water for Horsehay and Ketley furnaces, with autograph letter from R. R[eynolds], dated Jan., 1767.
92. Engraved book illustration; elevation and plan. Horizontal windmill. No date.
93. Engraved book illustration; elevation. "Blakey's fire engine for raising water." No date.
94. Aquatint; general elevation; plan and sections; scale 1.50. "Machine for cutting weeds on rivers and canals invented by A. de Betancourt," dated "Sept., 1796." Apparently from a Spanish book.
95. Engraved book illustration; no scale. Air pump and details. No date.
96. Pen-and-ink sketch; no scale. Unspecified. Perhaps copied from a book. No date.
97. Pen-and-ink sketch; no scale. "Mode of gettg. the Ironstone in Brockmoor Colliery, by T. Price. Mar., 1803."
98. Perspective was drawing; elevation. "Donnington Wood incline plane and engine, etc.," by William Minor. September 28th, 1793. William Reynolds introduced the inclined plane for canals to take the place of locks in 1788. (Compare 38 and 48 with this.)
99. Coloured drawing; sectional elevation; scale 1.60. Float wheel arranged to drive corn mill, by (?) A. de Bétancourt [1796.]
100. Coloured drawing; front and side views; scale 1.30. Details of roller and thrust bearings for 99.
101. Ink drawing; side elevation; scale 1.12. Watt type rotative engine with crank marked "Richard Speed, June 4th, 1796." Obviously a duplicate of Nos. 37 and 70.

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102. Coloured drawing; two plans superposed; scale 1.60. Float wheel arranged to drive a corn mill. No date. Part of set 99, 100 and 103.
103. Coloured drawing; elevation; scale 1.60. Float wheel arranged to drive a corn mill. No date. Part of set 99, 100 and 102.
104. Wash drawing; elevation and plan; no scale. Machine for transporting earth in making a cutting. No date. Duplicate of 105. (For details see Nos. 29 and 30.)
105. Coloured drawing; elevation and plan; no scale. "Machine pour transporter les terres." No date. Duplicate of 104, q.v.
106. Water-colour drawing; no size. Horse gin for transporting earth. No date, but paper has watermark 1794.
107. Water-coloured drawing; no size. Horse gin for transporting earth. No date. Duplicate of 106
108. Wash drawing; cross section and plan; scale 1.12. Cylinder cover. No date.
109. Wash drawing; plan; no scale. Horse run for transporting material. No date [1794.] Obviously cut off No. 21 q.v.
110. Ink drawing; elevation and sections; scale 1.240. Plan for a canal aqueduct with spans of 100 feet over a river. Signed "March, 1794, Thos. Telford." (Compare with No. 117.)
111. Perspective drawing. Fire engine for raising water, and description, copied from Emerson's "Principles of Mechanics," 1758.
112. Ink sketch and description; vertical section; no scale. Improvements in machinery for pumping, by R. Banks. No date.
113. A.L. from John Chinn, Tewkesbury, June 11th, 1798, to W. Reynolds, Ketley, with perspective sketch, back view, no size, and description of a catapult.
114. Ink sketch. "Frame or instrument to determine the strongest possible arch for a bridge," with long description. Dated Bridgwater, March 7th, 1796.
115. Coloured drawing; sectional elevation and plans; scale 1.12. "Cupola furnace put up at Coalbrookdale by Rogerson, wch. will melt two tons of scrap in a short time." By Jno. Hornblower, dated Jany., 1801.
116. Sepia drawing; front and side elevations; no scale. "Scotch barley mill." No date.
117. Ink drawing; two plans; scale 1.12. Cast iron framing for aqueduct showing alternative methods of connection. Signed "Thos. Telford." No date [1794.] (Compare with No. 110.)
118. Pen-and-ink drawing; sectional elevation and plan; no scale. "J. Wilkinson's Idea of Chimney Boiler given by him to W. R[eynolds], November, 1799."

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119. Engraving; scale 1in.=2 miles. "Plan of the intended Shrewsbury Canal, by George Young, 1793."
120. Engraving; scale 1in.=1 mile. "Plan of a canal from the parish of Mirthyr Tidvil to or near the town of Cardiff in the county of Glamorgan, by T. Dadford, 1790."
121. Engraving; scale 0.4in.=1 mile, or 1:153,800. "A plan of the navigable canal and collateral cuts between Birmingham, the different coal-mines, and the town of Walsall, with the proposed extensions." No date.
122. Coloured drawing; sectional elevation; scale 1.32. "Engine under James Glazebrook's patent." No date, but watermark 1798. Glazebrook's patents were: No. 2,164 A.D. 1797 and No. 2,504 A.D. 1801 for hot air engines.
123. Ink drawing; sectional plan and elevation; no scale. Steam wheel marked "J. Glazebrook, February 24th, 1799."
124. Ink drawing; elevation and plan; scale 1.48. "Inclined plane at Cyfarthfa," with legend. No date.
125. Ink drawing; sectional elevation and plan. Glazebrook's engine? No date.
126. Ink drawing; scale 1.4. Details of engine. No date. Apparently Glazebrook's patent engine.
127. Aquatint; scales 1.240 and 1.180. "Plan and section of a coalwork with the strata commonly met with in sinking near Wednesbury, Staffordshire." With legend in letterpress. Drawn by Thos. Westwood, engraved by F. Eginton, Birmingham. No date.
128. Aquatint; scales 1.240 and 1.180. "Perspective plan and section of a coalwork with the strata commonly met with near Wednesbury, Staffordshire." With legend in letterpress. Drawn by T. Westwood, engraved by F. Eginton. No date.

MEMORIAL TO "SCREW" SMITH.

A tablet on the wall of 31, High Street, Hythe, Kent, to the memory of Sir Francis Pettit Smith, F.R.S.E., who introduced the screw propeller for steam navigation, was unveiled on Wednesday, May 11th, 1922, by Lady Rocksavage. The tablet is the gift of the Rev. A. Winnifrith, M.A., D.Litt., whose researches have established the fact that it was at this house that the inventor was born on the 9th February, 1808. H.W.D.

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Analytical Bibliography of the History of Engineering and Applied Science 1900-1920.

Part I.

The following List deals mainly with articles in periodicals. The bulk of the entries for 1915-20 have been taken from the Class-Lists of "The Subject Index to Periodicals," issued by the Library Association—to which publication the Newcomen Society is a subscriber. The material for the period 1900-14 has been compiled from an examination of the files of "The Engineer," an analysis of the "Beiträege zur Geschichte der Technik, etc.," published by the "Verein Deutscher Ingenieure," abbreviated in this List to *B.G.T.*, and from a few special collections. Acknowledgment must also be made of assistance rendered by several Members of the Newcomen Society, who have furnished references to their own writings, etc. It is hoped that this form of assistance will be continued, and that contributors will send to the Hon. Secretary notes of papers of historical interest for incorporation in future Supplements. Members should note that under the arrangement with "The Subject Index to Periodicals" they can obtain through the Hon. Secretary of the Newcomen Society not only later entries on the subject of their enquiries, but also the loan of such periodicals as are filed in the Loan Library of the former body. London Members, however, will probably find it more convenient to study their literature in the Library of the Patent Office, which, with few exceptions, contains sets of all periodicals referred to in this List.

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Arab Industries—Technisches bei den Arabern. [building and mechanical] By E. Wiedemann. — *Geschichtsblätter f. Technik, etc.*, Vol. 6, 1919, pp. 24-30.

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Report of the Council
for Session 1921-22

PRESENTED AT

THE ANNUAL GENERAL MEETING, 1922,
HELD AT THE IRON AND STEEL INSTITUTE.

This, the Second Annual Report and Statement of Accounts, covers a critical period of the Society's existence, during which it has passed out of leading strings, so to speak, and has attained to the status of a fully developed Society. This has been accomplished by the adoption of a Constitution and of Rules at a Special General Meeting, the consequent retirement of the Committee which had managed affairs hitherto and the election of a Council at the first Annual General Meeting. Now that this is done and the first volume of the "Transactions" has been published, the Society may consider itself fairly launched upon the world.

The Council felt that a great deal depended upon making a proper start with the "Transactions," and a very considerable amount of time and trouble was spent in getting out something worthy of the Society and distinctive in format. Judging by the approval expressed by Members and by the favourable notices in the Press, the Council has been eminently successful. As a result, the number of Institutes and Libraries that have joined under Rule III has materially increased. The second Volume of Transactions is in active preparation.

The session has been one of steady progress, 24 new members having been elected; this appears small, but it is a very large percentage increase. The Society has to deplore the loss of one member by death. The total membership is now 125, exclusive of the libraries, etc., already alluded to. To carry out its aim a membership of about double this number is desirable.

Besides the two meetings mentioned above, three ordinary general meetings have been held. Ten papers in all have been presented at these meetings. The authors and dates of the papers ar as follows:—

G. F. Zimmer, Assoc.M.Inst.C.E. "The Early History of Mechanical Handling Devices." October 12th.

C. F. Dendy Marshall, M.A. "The Liverpool and Manchester Railway." November 16th.

R. C. Walters, B.Sc., Assoc.M.Inst.C.E. "Greek and Roman Engineering Instruments." December 15th.

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T. E. Lones, M.A., B.Sc., L.L.D. "Mechanics of Engineering from the time of Aristotle to that of Archimedes." January 24th.

Robert Young, M.I.Mech.E. "Timothy Hackworth and the Locomotive." March 1st.

Eng. Capt. E. C. Smith, O.B.E., R.N. "The Centenary of Naval Engineering." March 30th.

Conrad Matschoss, Ph.D., Dr.Ing. "A holograph letter of Newcomen." April 27th.

Loughnan St. L. Pendred, M.I.Mech.E. "A Note on Brunton's Walking Engine, 1813." April 27th.

A. Titley, M.I.Mech.E. "Notes on Heaton's Steam Carriage, 1830." April 27th.

E. A. Forward, A.R.C.S. "Gurney's Railway Locomotives." April 27th.

It will be observed that four of these were presented on one evening. They were short papers, and the intention was to encourage communications which were perhaps not of sufficient moment to occupy a whole evening. Most of the above meetings were reported at the time in the Press, and the papers will appear in the "Transactions" in due course.

Besides these, a summer meeting of two days' duration was held in June. Visits were paid to the Science Museum, South Kensington, where the party was received by the Director; to Westminster Hall roof, where Sir Frank Baines, C.V.O., gave a short lecture on the repairs to the roof and personally conducted the members over the work; to the horological collection of the Clockmakers' Company at the Guildhall, where the party was received and entertained by the Deputy Master, Mr. T. A. Bullock, and where the collection was explained by Mr. Inkerman Rogers, F.G.S.; to the Rotunda Artillery Museum at the Rotunda, Woolwich; to the Naval Museum and the Painted Hall, Greenwich; to the Deptford Pumping Station of the Metropolitan Water Board, where the District Engineer, Mr. F. W. Melhuish, showed two old Boulton and Watt pumping engines with their boilers. The meeting, with its social intercourse and dinner on the first evening, were greatly enjoyed by all who took part. Short notes on the places visited and a guide to notable spots in London were prepared for the occasion by three of the members.

As a result of these activities the Society is becoming more widely known.

A number of enquiries for technical information have been received from Members, and in each case the Secretary either directly, or by putting Members into touch with others in the same line of research, has been able to supply the information wanted.

The financial position of the Society continues to be satisfactory, as will be seen by the Treasurer's statement. After paying for the printing of the "Trans-

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actions " and all other expenses there is an available balance of £86; but it must be remembered that this is earmarked for the printing of Volume II. of the " Transactions," which ought really to be a charge on this year's revenue. As time goes on it is hoped to have the " Transactions " in member's hands shortly after the close of each session. As will be seen, a certain revenue has accrued from the sale of " Transactions." In addition, the stock thereof has not been valued. A satisfactory feature is that the summer meeting did not result in any charge on the Society's funds.

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NEWCOMEN SOCIETY.

Revenue Account from 1st October, 1921, to 30th September, 1922.

Dr.

Expenditure.	£ s. d.	£ s. d.
To Hire of Rooms and Expenses of Ordinary and Summer Meetings	23 11 0	
Printing and Stationery, including preparation and printing of "Transactions," Vol. I.	65 11 3½	
Typing and Mimeographing	9 12 7	
Postage, telegrams, parcels, stamps and travelling expenses	12 7 4½	
Bank Charges and Commission	0 7 11	
		111 10 2
Excess of Income over Expenditure for the Year		26 10 1
		£138 0 3

Cr.

Income.	£ s. d.	£ s. d.
By Subscriptions and Donations for the Year	109 10 9	
Members' and Visitors' Contributions to Summer Meeting	15 9 0	
Sale of "Transactions"	11 15 0	
Bank Interest to 30th Sept.	1 5 6	
		138 0 3
		£138 0 3

Balance Sheet of the Society as at 30th September, 1922.

Liabilities.	£ s. d.	£ s. d.
Balance brought forward from 31st October, 1921	55 0 0	
Surplus from Revenue Account ending 30th September, 1922	26 10 1	
		81 10 1
Subscriptions paid in Advance		5 0 0
		£86 10 1

Assets.	£ s. d.	£ s. d.
Cash as under:—		
On Deposit	70 0 0	
On Current Account	10 17 8	
In Treasurer's hands	5 12 5	
		86 10 1
Stock of "Transactions" (not valued)		— — —
		£86 10 1

The above Accounts have been examined with the Books and Vouchers, and found correct.

(Signed) A. M. BUSHELL, Hon. Auditor.

(Signed) H. W. DICKINSON, Treasurer.

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The Newcomen Society

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JANUARY, 1923.

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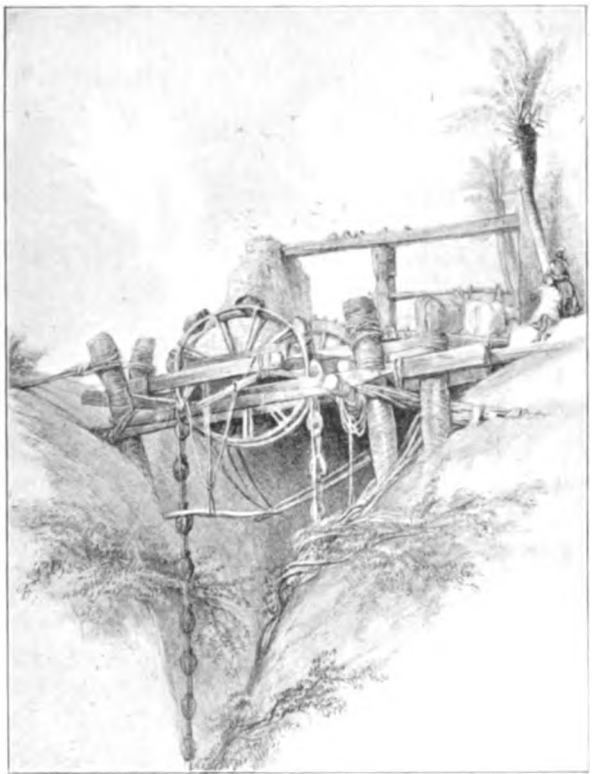
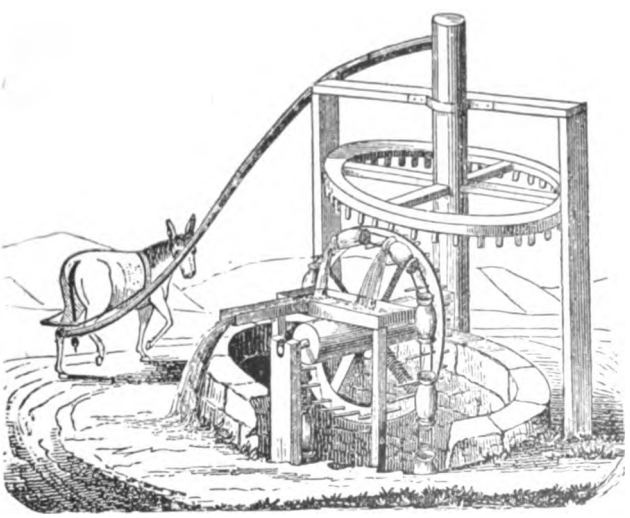
PLATE I.



CHAIN OF POTS.
As used today in Egypt and the East.
From Roberts's "Holy Land," 1855.



CHAIN OF POTS, SAKIA OR PERSIAN WHEEL.
From Ewbank's "Hydraulics," 1842.

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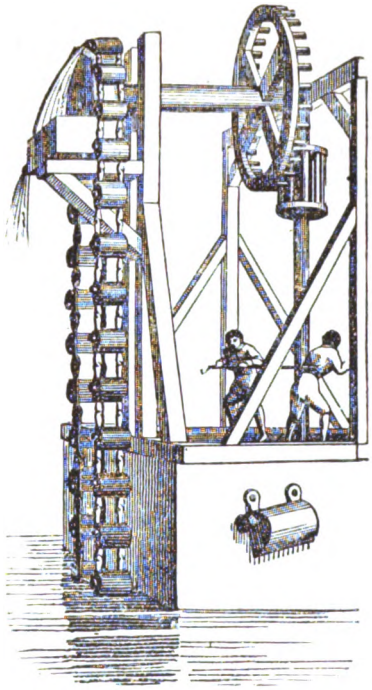
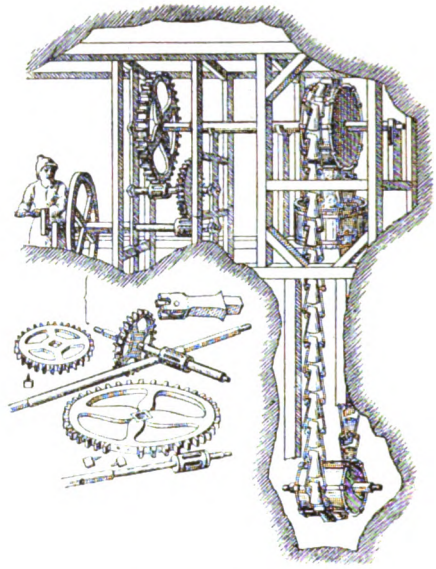
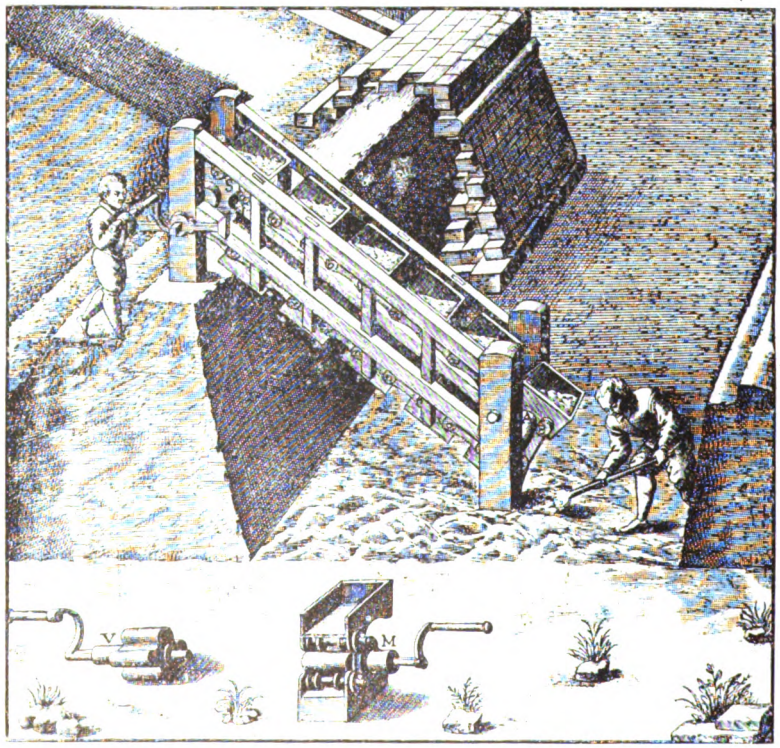


ROMAN ELEVATOR
as described by Vitruvius.
From Ewbank's "Hydraulics," 1842.



CHAIN OF POTS
for Mine Drainage.
From Agricola's "De Re Metallica," 1556.



INCLINED BUCKET ELEVATOR.
From Ramelli's "Le Diverse et Artificiose Machine," 1588.

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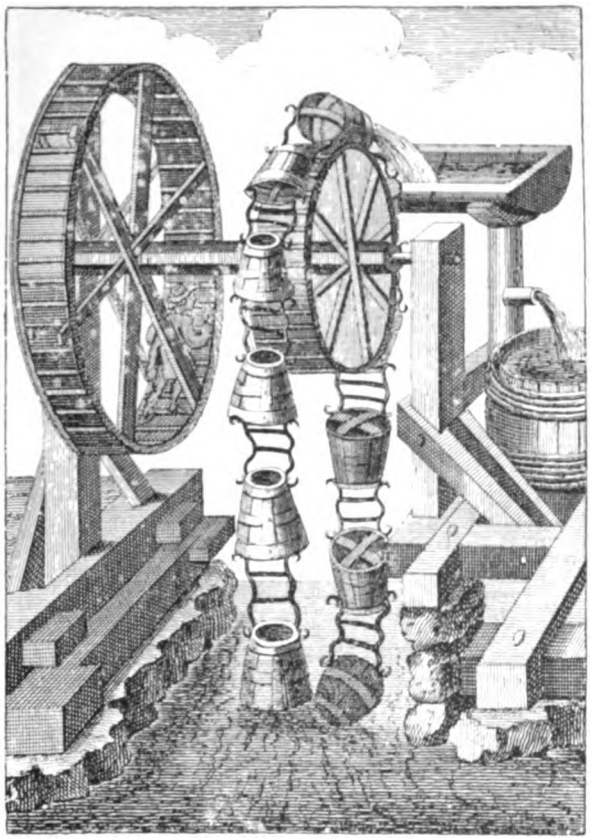
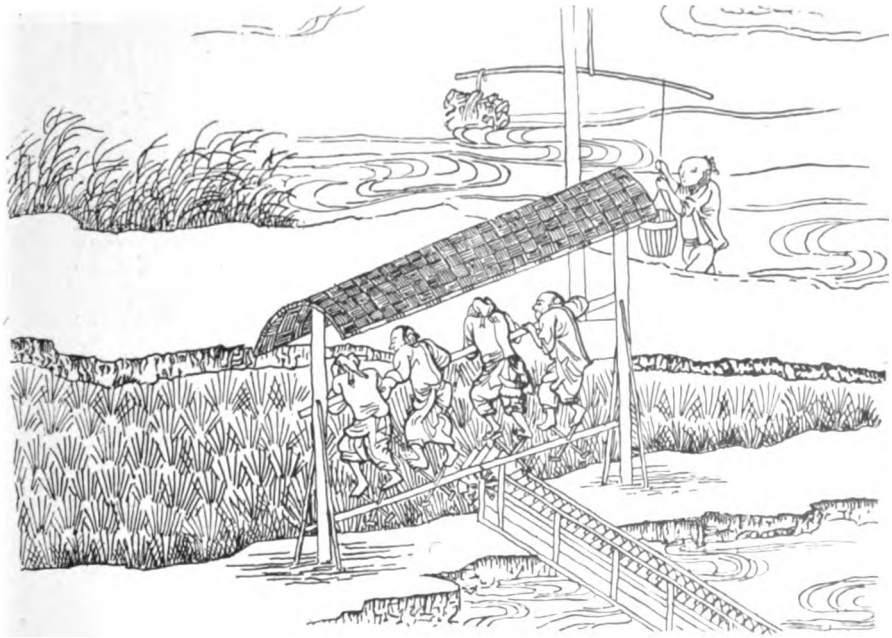


BUCKET ELEVATOR
used at Bruges in 1063.
From Kircher's "Mundus Subterraneus," 1665.



CHINESE CHAIN PUMP.
Described in "K'ien-Ling Keng Tschi t'u," A.D. 1145.

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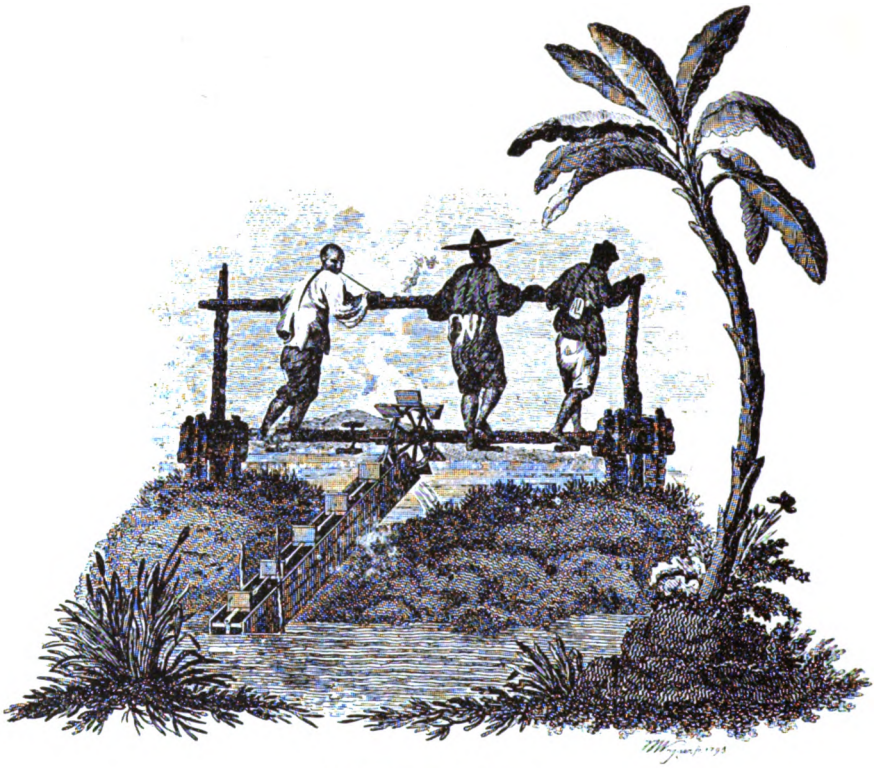

CHINESE CHAIN PUMP.
From Staunton's "Embassy to the Emperor of China," 1796.

CHINESE CHAIN PUMP OR PUSH PLATE CONVEYOR.
From Colesworthy Grant's "Rural Life in Bengal," 1860.

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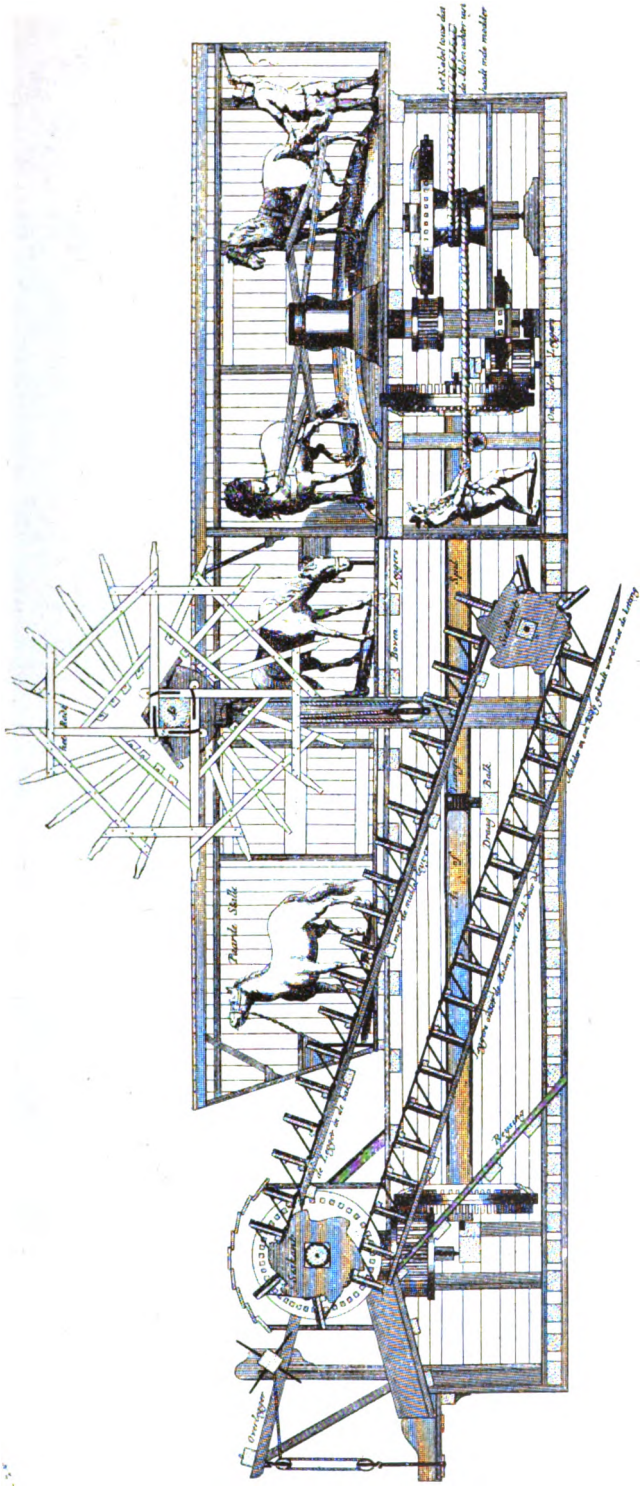

PUSH PLATE CONVEYOR
mounted on a Pontoon for use Dredging Mud.
From van Zyl's "Theatrum Machinarum Universale," 1734.

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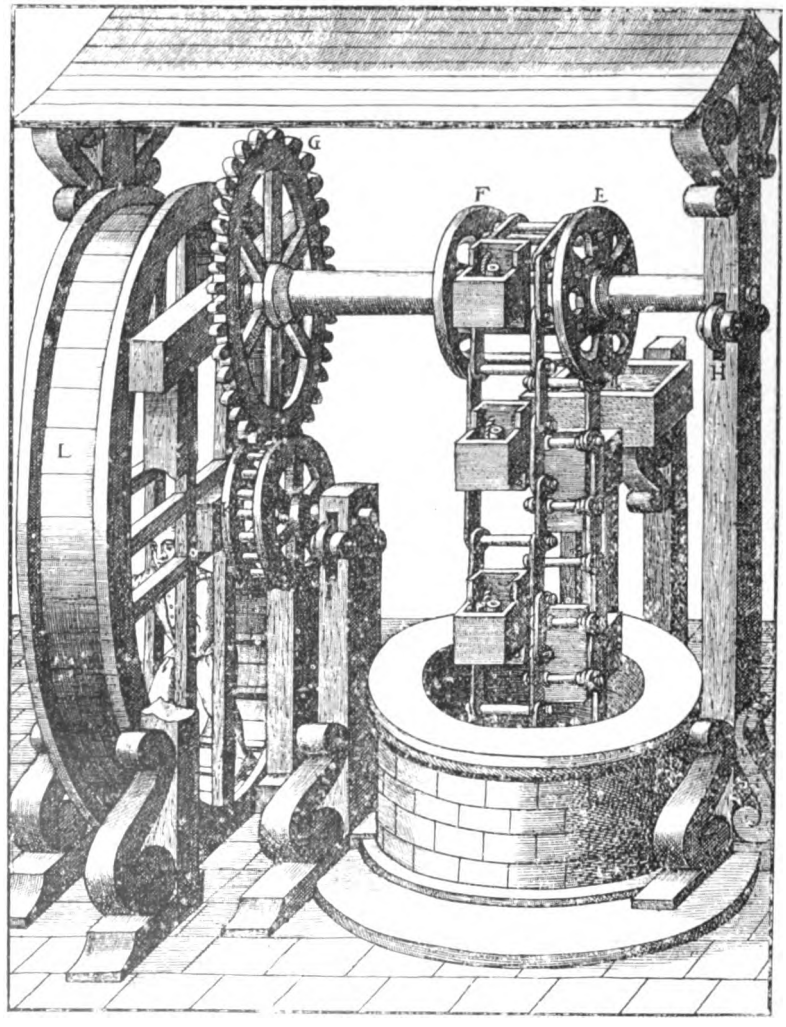

BUCKET ELEVATOR.
From Ramelli's "Le Diverse et Artificiose Machine," 1588.

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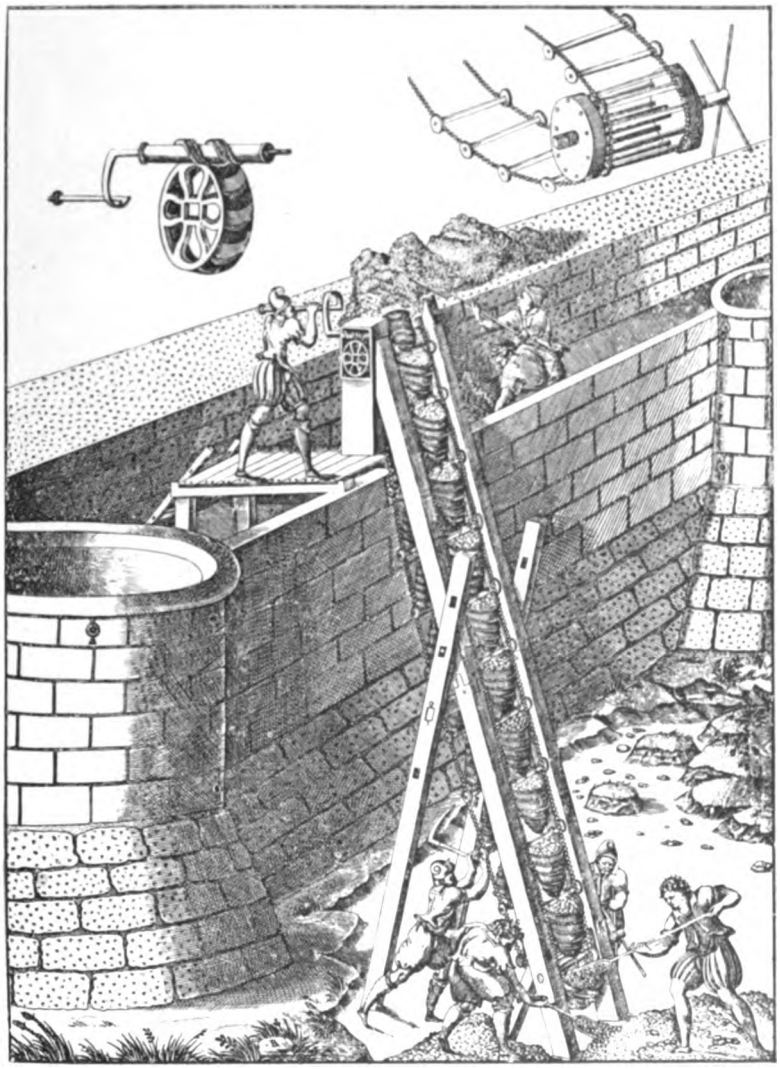
PLATE VII.



BUCKET ELEVATOR
for Raising Building Materials.
From Besson's "Theatre des Instrumens," 1578.

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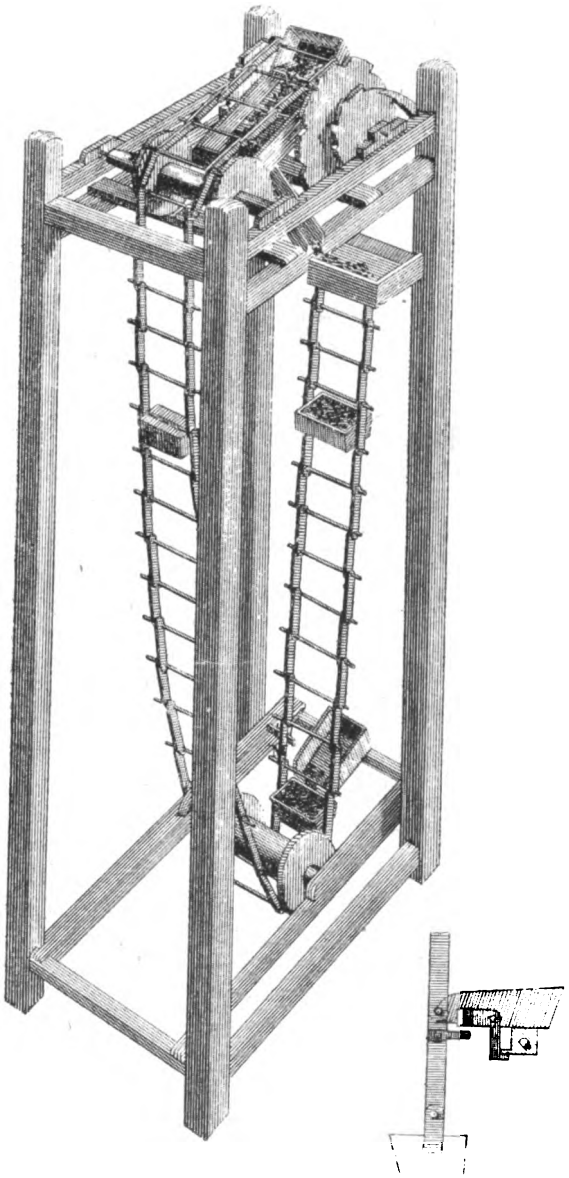
PLATE VIII.



ARKWRIGHT'S GRAVITY BUCKET ELEVATOR
for use in Mines.
From "The Repertory of Arts, etc.," 1802.

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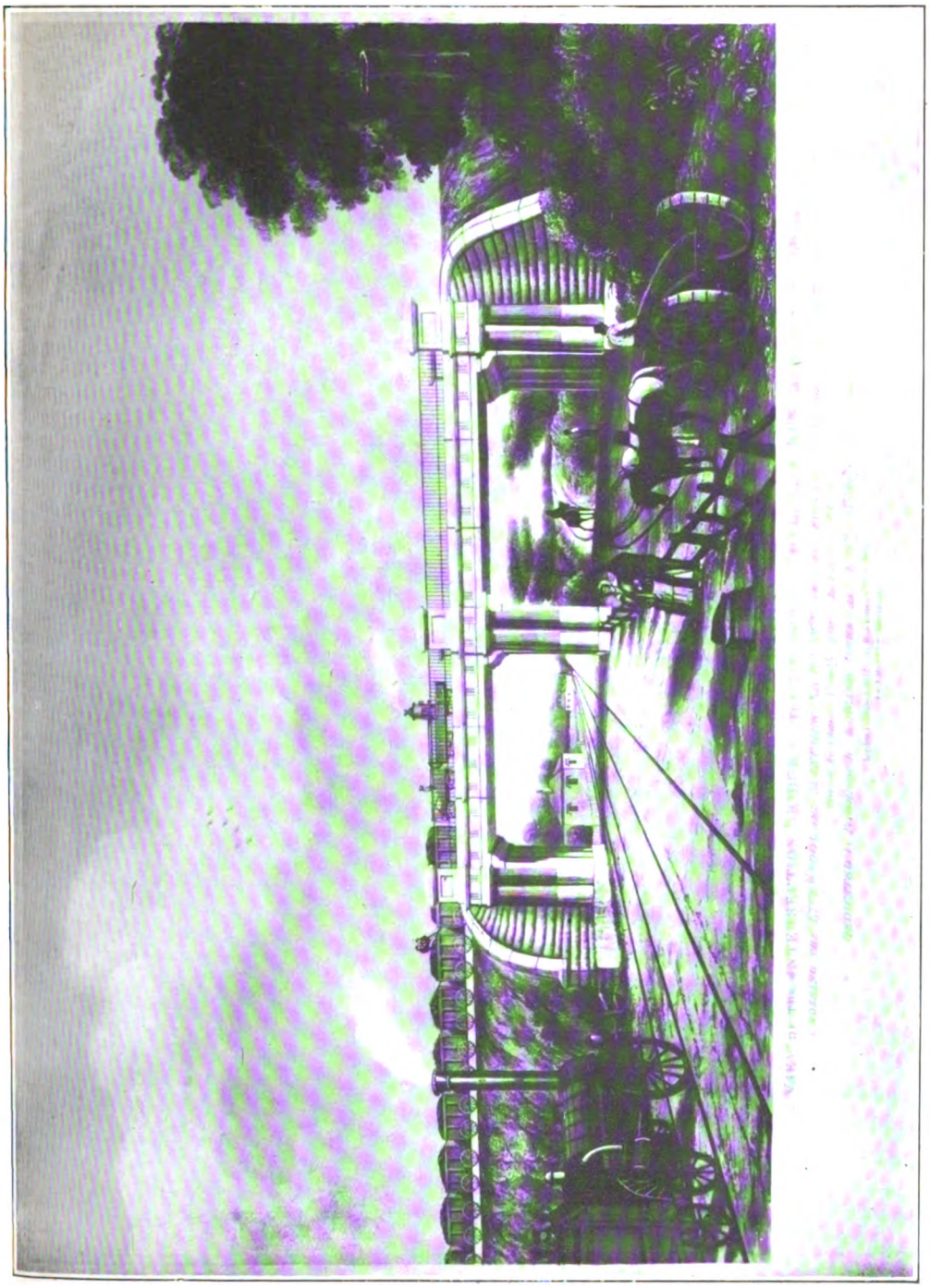

BRIDGE OVER THE LIVERPOOL AND MANCHESTER RAILWAY AT SUTTON
Showing the "William the Fourth" Locomotive.
From the Aquatint by Hughes, 1832.

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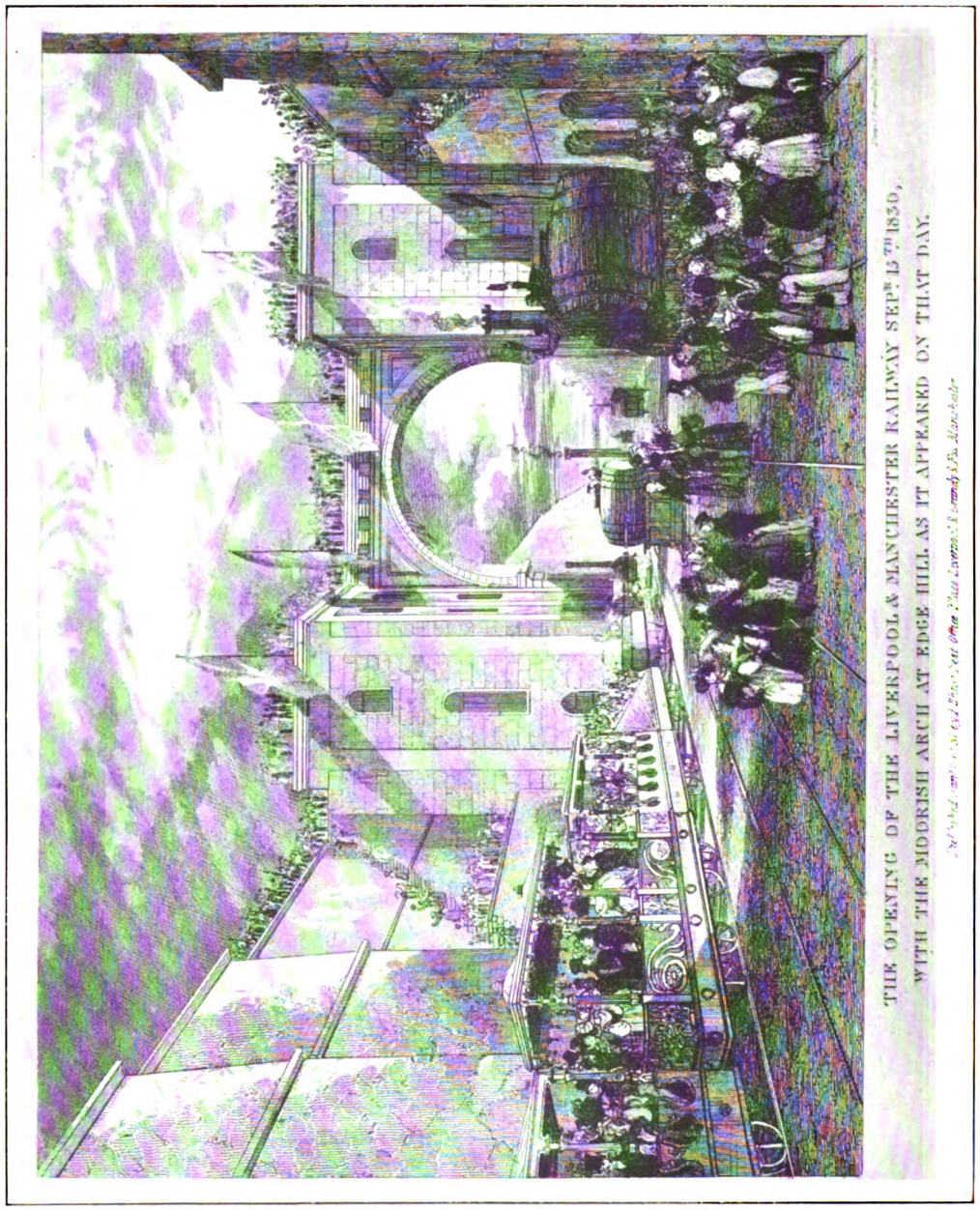

OPENING OF THE LIVERPOOL AND MANCHESTER RAILWAY, 1830
From the Engraving by Shaw, 1831.

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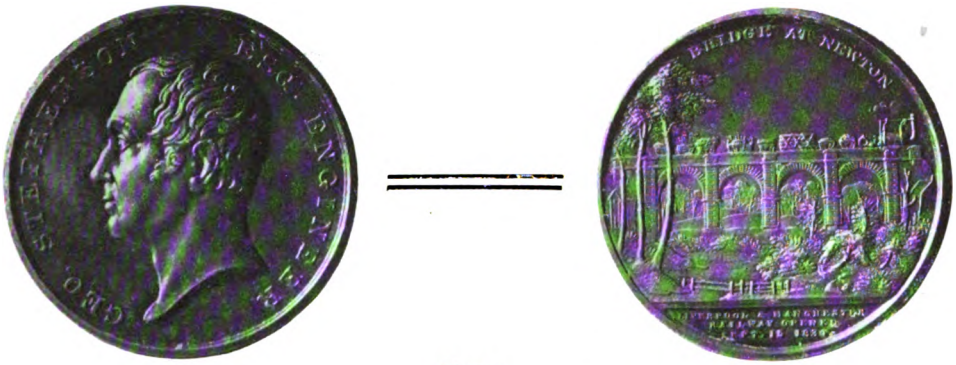

MEDAL
COMMEMORATING OPENING OF LIVERPOOL AND MANCHESTER RAILWAY.
Struck 1830. Actual size.

POTTERY JUG
REPRESENTING OPENING PROCESSION, LIVERPOOL AND MANCHESTER RAILWAY, 1830.

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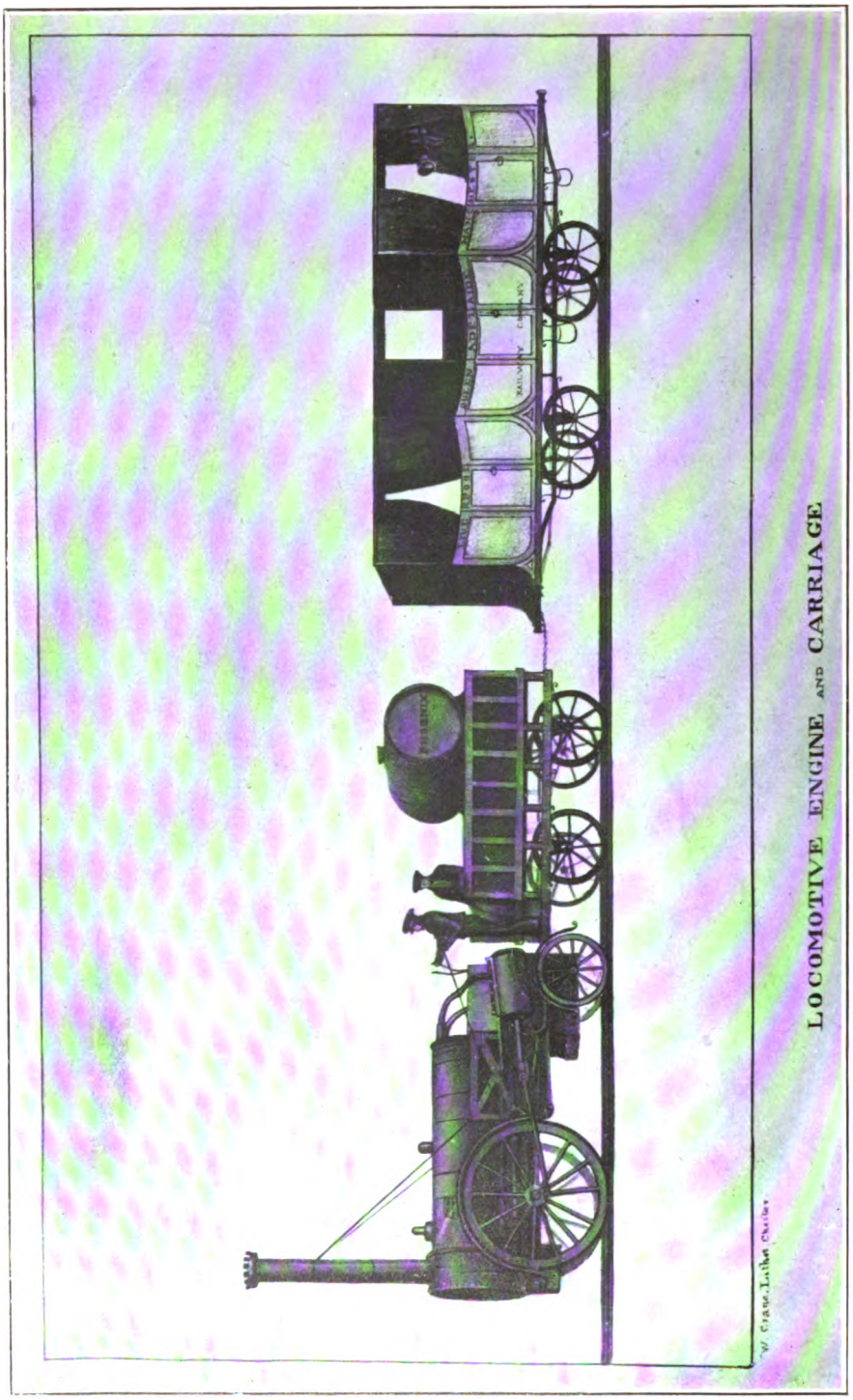

Phœnix Locomotive, Tender and Passenger Coach, 1831.
From the Lithograph by Crane.

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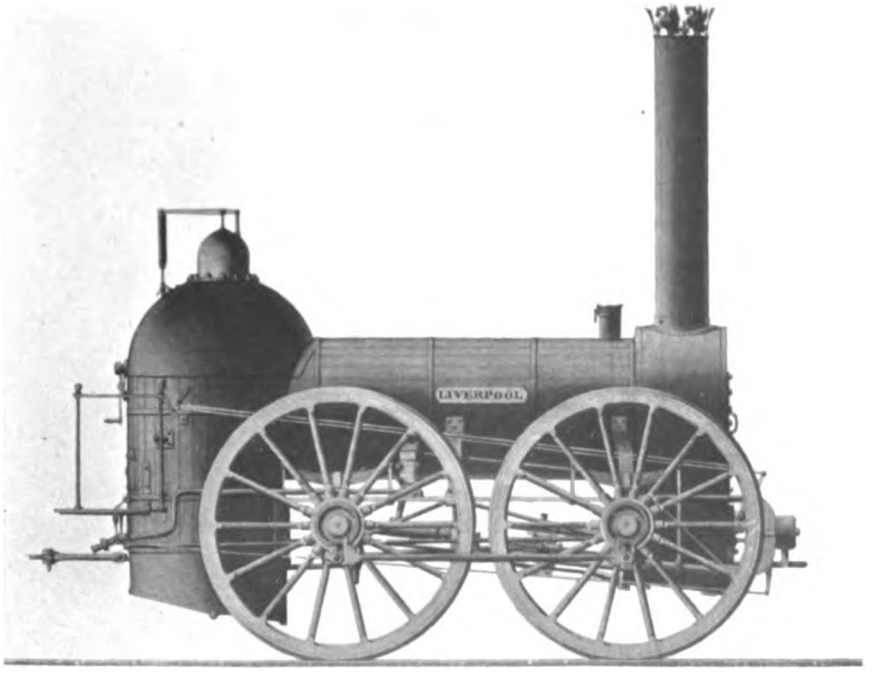
PLATE XIII.



BURY'S LOCOMOTIVE, LIVERPOOL.
From an Original Drawing by Edward Bury.

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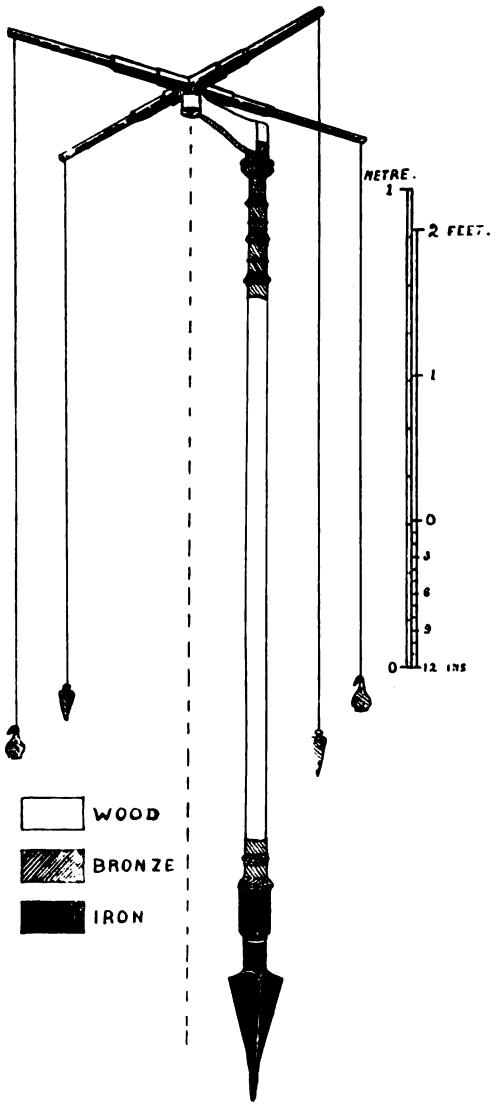

GROMA
Discovered at Pompeii in 1912.
As restored by Della Corte.

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PLATE XV.

TIMOTHY HACKWORTH

In the fifty-fourth year of his age.
From the Original Oil Painting in the Author's possession.

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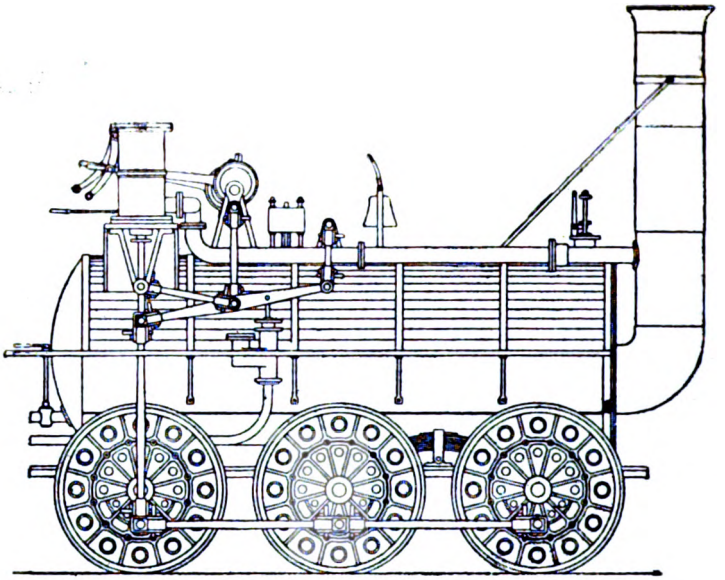
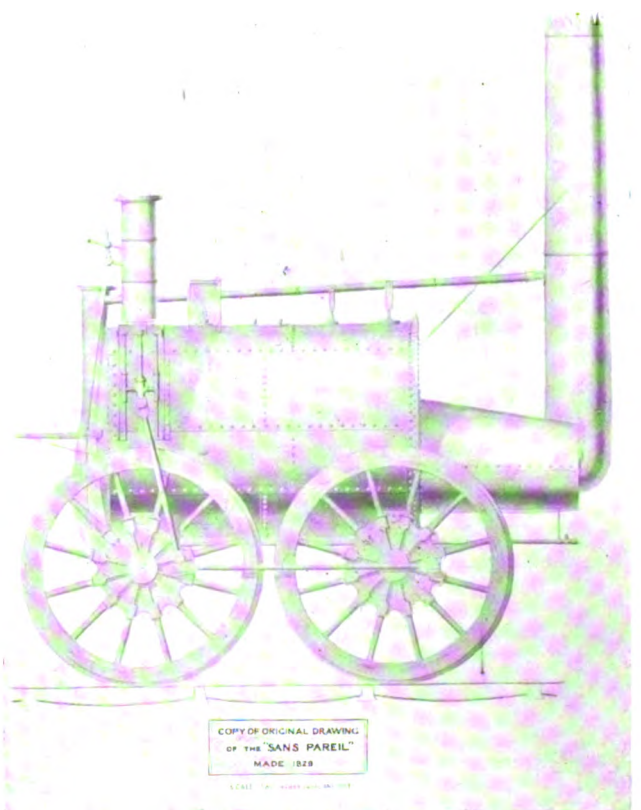


ROYAL GEORGE LOCOMOTIVE, 1827.
From a Drawing, formerly in the possession of J. W. Hackworth.



SANSPAREIL LOCOMOTIVE, 1829.
From a copy of the Original Drawing in the Science Museum.

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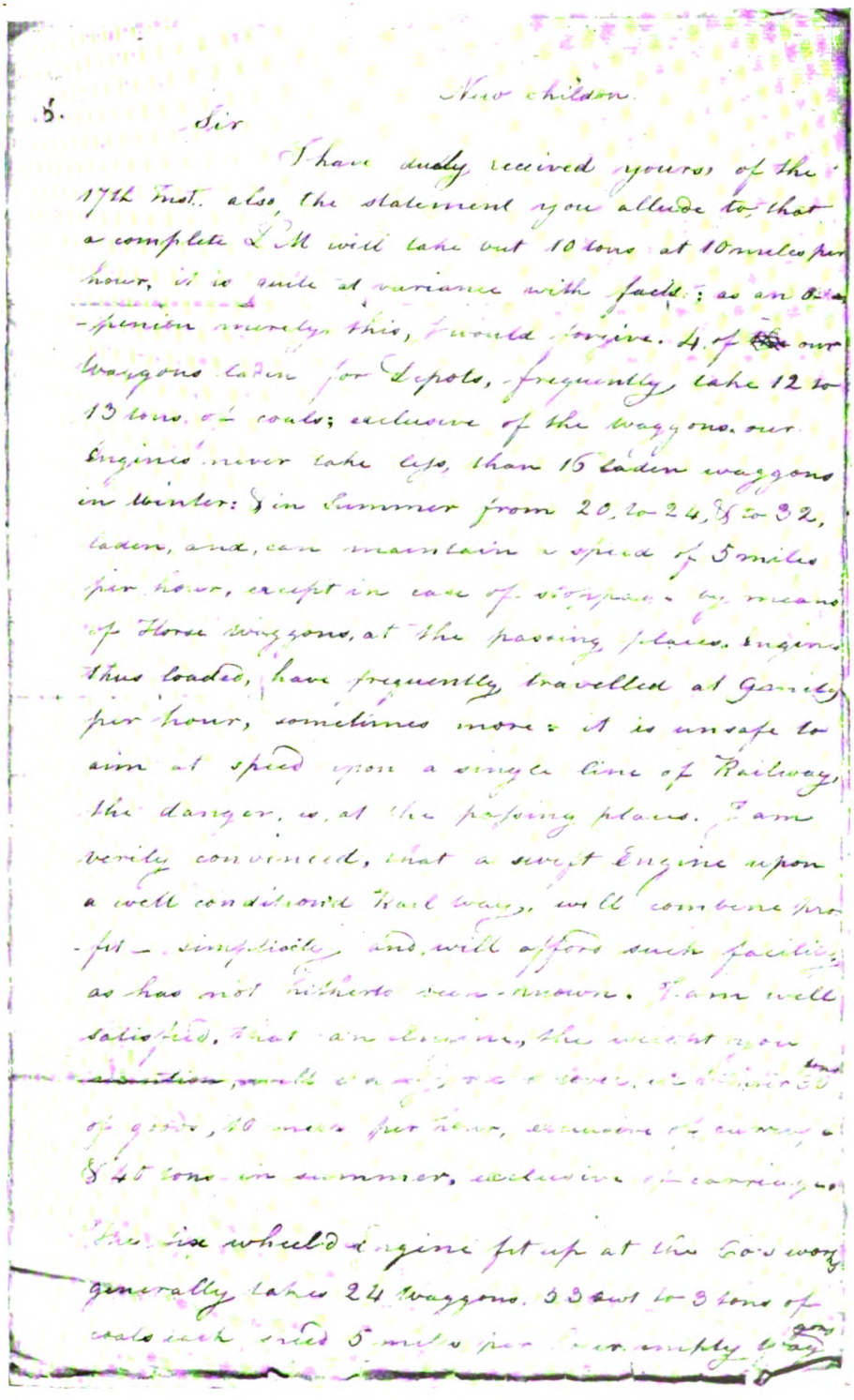
PLATE XVII.



5. New Childon.

Sir

I have duely received yours of the 17th Inst. also, the statement you allude to, that a complete L M will take but 10 tons at 10 miles per hour, it is quite at variance with facts; as an Oc-pinion merely this, I would forgive. 4. of our waggons laden for Depots, frequently take 12 to 13 tons of coals; exclusive of the waggons. our Engines never take less, than 16 laden waggons in winter: & in Summer from 20, to 24, & to 32, laden, and, can maintain a speed of 5 miles per hour, except in case of stoppage by means of Horse waggons, at the passing places. Engines thus loaded, have frequently travelled at 9 miles per hour, sometimes more: it is unsafe to aim at speed upon a single line of Railway, the danger, is, at the passing places. I am verily convinced, that a swift Engine upon a well condition'd Rail way, will combine pro-fit — simplicity, and, will afford such facility, as has not hitherto been known. I am well satisfied, that an Engine, the weight you mention, will [illegible] 30 tons of goods, 10 miles per hour, exclusive of carriage & 40 tons in summer, exclusive of carriage.

The six wheel'd Engine fit up at the Co's work generally takes 24 waggons. 53 cwt to 3 tons of coals each speed 5 miles per hour empty waggons

DRAFT OF LETTER
From Hackworth to the Directors of the Liverpool and Manchester Rly. Co.
November, 1829.
Original in the possession of the Author.

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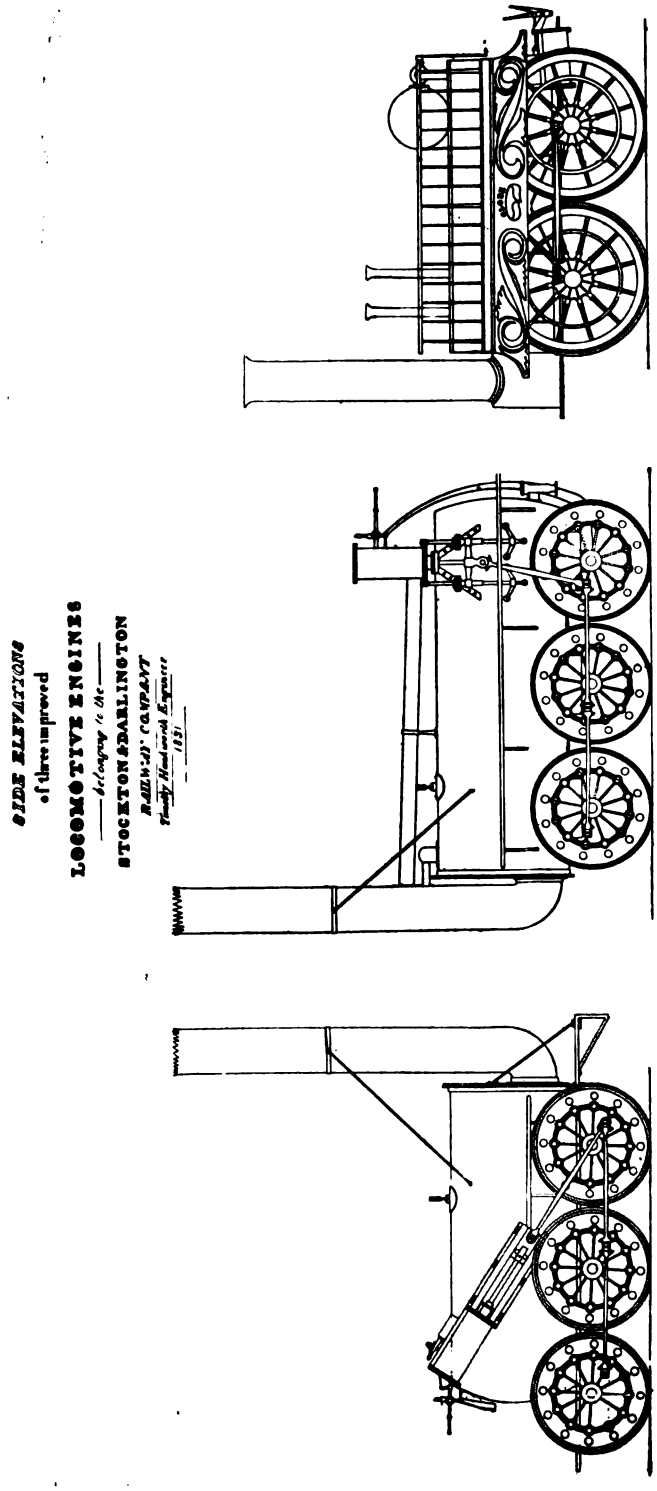

VICTORY, PLANET AND GLOBE LOCOMOTIVES, 1831.
From an Original Drawing in the possession of the Author.

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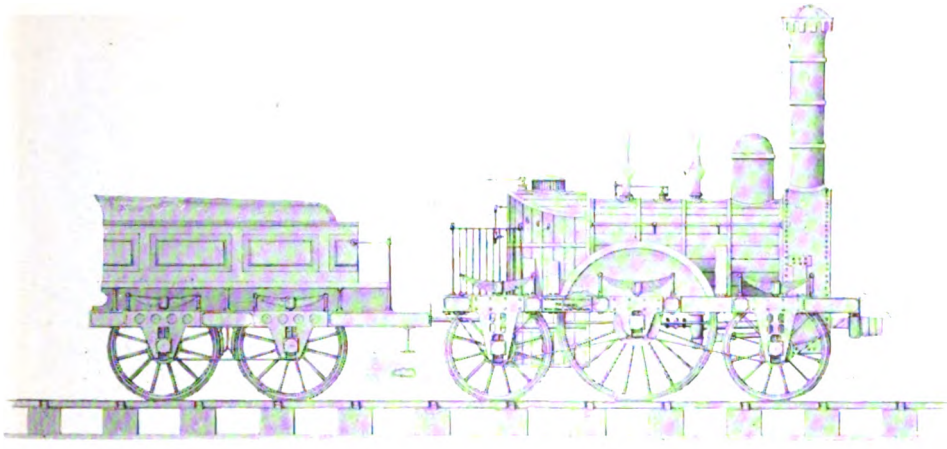
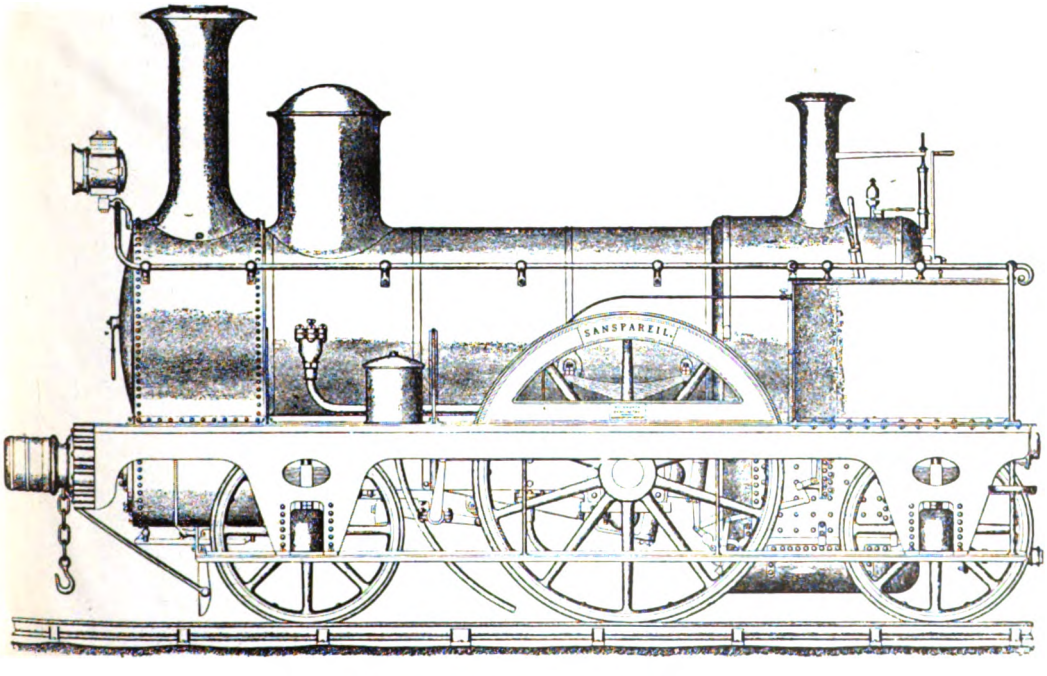


HACKWORTH'S LOCOMOTIVE FOR RUSSIA, 1836.
From the Original Drawing in the Author's possession.



SANSPAREIL LOCOMOTIVE, 1849.
From a Lithograph in the Author's possession.

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Recto.

ace. Darmst. 1919. 322.

My Lord

It having pleased God in his Allwise Providence in some measure to disappoint us by the Death of Mr John Calley, who was sent to Holland, in order to procure a Patent there for our New invented Wind Engine or Machine, I presume to give yor Lordship the trouble of these Lines, making my humble acknowledgments for the many Favours already received from you on that Occasion, particularly for yor kind recomendation of us to a Person of so much Honour and Benignity as Sr Matthew Deyker, who was pleased not only to favour us with his own Letter to a very worthy Gentleman, but also to procure another for us from the Dutch Ambassador to the Great Man at the Hague, which had all the good Effect that could well be desired, and the Affair was like soon to be brought to a good Issue, had it not been prevented by the Decease of our Agent there: But whilst I am acknowledging past Favours, the Circumstances of our Affair obliges me to inform yor Lordship that we stand in need of further Assistance; for designing not to lose the fair Prospect we have of Success in it, the Persons concerned have agreed to send my Nephew Mr George Newcomen to Holland, in order to perfect that which hath been so happily begun; and supposing it will be very proper, if not necessary, that he should also be well recomended on his going thither as the Person who is to succeed Mr Calley in the Prosecution of that Affair: If yor Lordship is of the same Opinion I humbly hope & desire you would be pleased to favour us with a fresh Recomendation to Sr Matthew, who I persuade my self will be so good as to renew his former Favours, and thereby compleat the Benefit he intended us, the full Effect of which hath hitherto been providentially prevented.

My Nephew, Mr Elias Newcomen, who is to wait on yor Lordship with this, will be ready to observe what Directions you shall be pleased to give him herein, and I shall alwayes be ready to acknowledge it as a great Addition to the many Obligations I already ly under; & with tenders of all due Respects am

My Lord yor Lordships very humble and Obedient Servant

Tho: Newcomen

Dartmo. May 7th 1725

To the Right Honourable
The Lord Chief Justice King

Verso.

LETTER FROM NEWCOMEN TO LORD CHANCELLOR KING.
Preserved in the Staatsbibliothek, Berlin.

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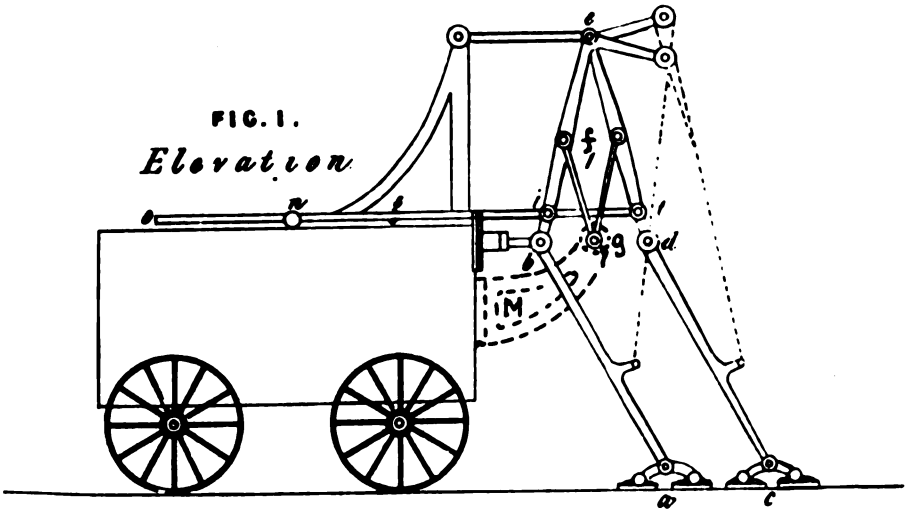
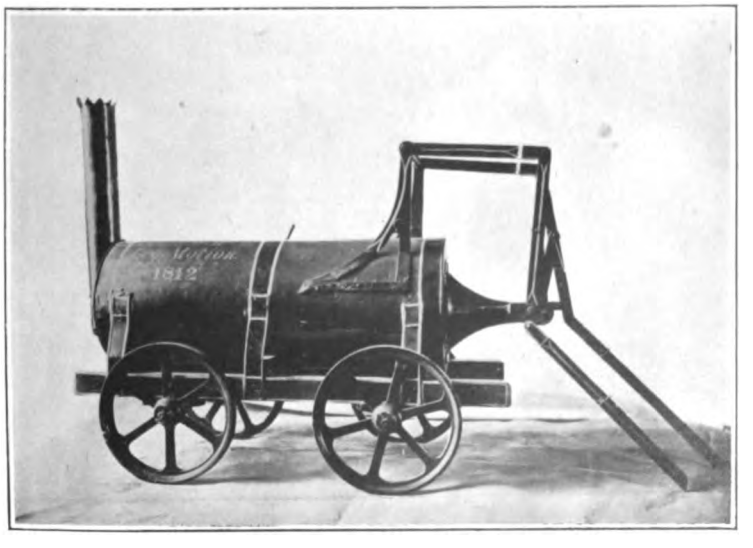


BRUNTON'S STEAM HORSE, 1813.
From the Patent Specification Drawing.



MODEL OF BRUNTON'S STEAM HORSE.
Present owner unknown.

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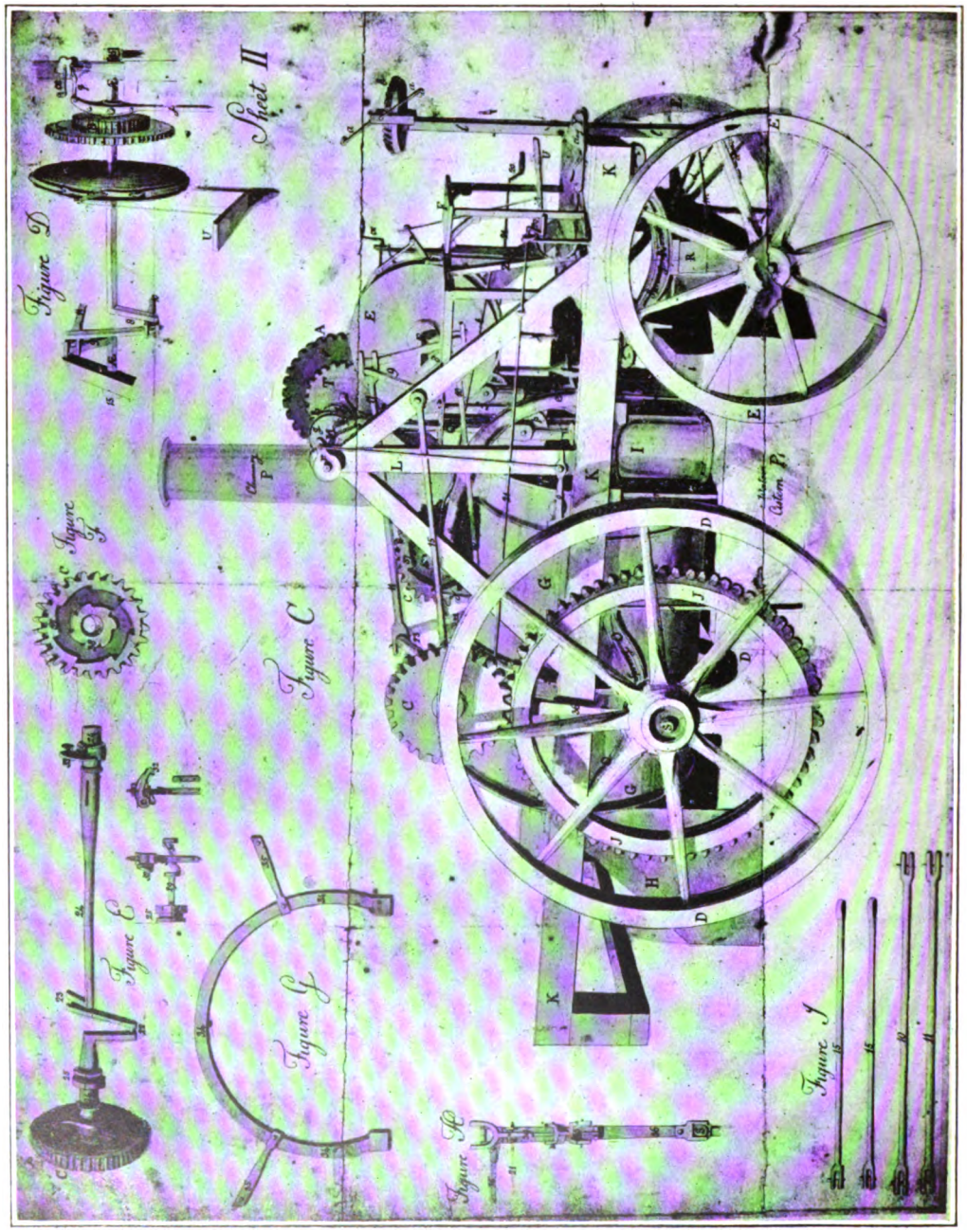

HEATON'S STEAM CARRIAGE, 1830.
From the Original Drawing now in the Birmingham Free Reference Library.

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for the study of the history of

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EMBLEM OF THE SOCIETY.

On this volume appears the emblem that the Council has adopted after much deliberation. Devices, such as a Newcomen engine, that might seem to identify the Society with one particular aspect of its activities, were considered but rejected. Recourse was had to a heraldic device, and the griffin, emblematic of vigilance, was finally adopted. The beast is represented looking backward while yet going forward. The motto, due to Col. Kitson Clark, Member, expresses this idea; it may be freely rendered: " Mindful of what has been done, we strive at the same time after the things yet to be done."

CORRIGENDA IN TRANSACTIONS, VOL. II.

P. vi., l. 12, for " W. W. Greener " read " C. E. Greener."
P. 126, l. 3, for " D. S. Levien " read " D. V. Levien."
P. 162, l. 7, for " D. Y. Levien " read " D. V. Levien."
Plate XVII. in title for " Directors of the Liverpool and Manchester Railway " read " Robert Stephenson."
Plate XVIII. in title for " Victory, Planet and Globe " read " Rocket, Victory and Globe."

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Simon Goodrich and his Work as an Engineer

Compiled from his Journal and Memoranda

By E. A. Forward, A.R.C.Sc., M.I.Mech. E.

Pt. I.. 1796-1805.

(*Read at Prince Henry's Room, Fleet Street, October 26th,* 1922.)

In considering engineering history, the early part of the nineteenth century is one of the most interesting periods. Watt's patent had just expired, and condensing steam engines were being produced in increased numbers, while their application to industry in general was much accelerated. Trevithick's high pressure engine also entered the field at this time, and free and rapid development took place.

The writer has recently examined the papers[1] left by an engineer who flourished at this time, and this paper has been prepared from the information contained therein. The engineer in question, Simon Goodrich, was a Government official whose name is now unknown to the world in general, but who appears to have been well-known to contemporary engineers. He was born on October 28th, 1773, his father, Isaac Goodrich, being, it is believed, a Suffolk man. His birthplace is not known, and we are ignorant of particulars of his early education or professional training. His official career, however, is clear from his notes. He was appointed as draughtsman to the mechanist in the office of Sir Samuel Bentham, K.B., Inspector General of Naval Works, on December 25th, 1796. On October 25th, 1799, he was appointed as mechanist at a salary of £400 per annum, and he held that position until December 25th, 1812, when the Inspector General's Office and staff were abolished. During two years of this period—August, 1805, to November, 1807—he acted as deputy for Bentham while absent in Russia. After being employed as mechanist without warrant until April, 1814, he was reappointed as engineer and mechanist to the Navy Board, with a salary of £600 per annum; this post, which involved residence at Portsmouth, he occupied until 1831, when he retired on a pension of £400 per annum. In 1834 he went to Lisbon, and died there on September 3rd, 1847.

[1] Preserved at the Science Museum, South Kensington, London.

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During the greater part of Sir Samuel Bentham's period of office, Goodrich was his chief assistant, and he carried into effect the various engineering schemes prepared by Bentham for the Dockyards. After that time he had the management of the engineering works in the Dockyards, and was consulted by the Navy Board on all such matters which were submitted to them. His position thus brought Goodrich into contact with most of the well-known engineers of the day, and numerous letters from such are amongst his papers. He kept a daily journal and memorandum book, but this is not uniformly complete over the whole period covered, which extends from 1802 to 1845. These books contain interesting references, often with sketches, relating to the engineering works of all kinds which came under his notice, and from these a selection has been made.

Perhaps the principal achievements of Bentham were the introduction, against great opposition, of steam engines into the dockyards, and the setting up of the wood mills, metal mills, and millwrights' shop, in Portsmouth Dockyard, for the more economical manufacture of naval requirements. The success of these establishments is indicated by the facts that the saving on the blocks made during 1808 was nearly £17,000, while that on the work done in the metal mills during 1812 was nearly £41,000.

The first steam engine at Portsmouth, one of 12 h.p., was put up early in 1799 to pump water out of the dock basins. This engine had been made a year or two earlier for driving the wood-working machinery which was to have been erected at Redbridge, where some of Bentham's experimental vessels were being built, but as it was not ready until the ships were finished, it and the machines were stored at Portsmouth until needed there. The engine was made to the design of James Sadler, of whom little is known, but by whom the engine was made is uncertain. It was a single-acting rotative condensing engine, with a cylinder 28in. diam. by 36in. stroke. It had no beam or parallel motion, but had a roller crosshead and guides with return connecting rods to a crank-shaft beneath the cylinder. It seems probable that Sadler was the originator of this "table" form of direct-acting engine, as drawings of his in the Coalbrookdale sketch book,[2] dated as early as 1795, show this arrangement. An engine of Sadler's was described in Nicholson's *Philosophical Journal* in 1798, and is said to have been patented, but no such patent is recorded. Its special feature consisted in using the air pump as a combined pump, jet condenser and working cylinder, but the engine under notice is simpler than that described, although it appears to have a water jet at the bottom of the air pump as well as a jet at the bottom of the cylinder. The piston rose in a vacuum, while the air rod pump was connected to the middle of a pivoted lever, the end of which was linked to the crosshead. This design was copied by Goodrich for other engines, and must have been seen by Maudslay on his numerous

[2] "Trans." Vol. II., p. 133 (5) and 137 (75).

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visits to the dockyard, so that it may have led to the latter's improved design of table engine patented in 1807.

In a return of the Mechanist's work, prepared for the Committee of Revision in 1806, Goodrich records that the engine drove a large lifting pump capable of raising seven tons of water per minute, and replaced the horses previously used.

The need for more power was soon apparent, and plans were under consideration, in October, 1799, for a 30 h.p. engine, which was to work six chain pumps 2ft. diam. each capable of raising 10 tons of water per minute. This engine was made by Messrs. Boulton and Watt,[3] and there are several letters, during 1800, relating to it. An estimate, dated Soho, December 12th, 1799, quotes, for a 30 h.p. engine, the sum of £1,050 for all the metal work, including one iron boiler, but excepting the ironwork for screwing the framing and cistern together. A second estimate, of February 5th, 1800, quotes for a similar engine, with a cylinder 28.5in. diam. by 6ft. stroke, with a crank motion fixed to it, the sum of £1,070 plus the cost of carriage to Portsmouth. Drawings of the framing and engine house were to be furnished without further charge, and an engineer provided for the erection of the engine, whose wages were to be charged at 30/- per week. Delivery could be given in three or four months, and payment was to be made on receipt of the materials.

A letter written by Gregory Watt, on April 26th, 1800, gives a list of prices of rotative engines of different sizes which is of interest. It is as follows:—

4 horse	engine	including	one iron boiler	...	£327
10	,,	,,	,,	...	£491
20	,,	,,	,,	...	£750
30	,,	,,	,,	...	£1,050
40	,,	,,	,,	...	£1,440
50	,,	,,	,,	...	£1,727

The smaller engines could be delivered in three months, and the larger in between three and four months from order.

A letter from John Southern, dated April 29th, 1800, says that Boulton and Watt had no experience of burning cinders and little of burning wood (as was stipulated at the Dockyard), but suggested a grate area of 36 sq. ft. instead of 22 sq. ft. as for coal. The engine was under construction in June, and the parts were sent to Bristol for conveyance to Portsmouth in September, 1800. A list of these parts exists, from which it appears that the valves were of copper operated by racks, and their spindles were steeled. The boiler was in 22 pieces, and there were included a box of pomatum and three boxes of cement, presumably for the joints.

[3] The drawings are preserved in the Boulton and Watt Collection at the Birmingham Free Library.

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This engine differed somewhat in its arrangement from the standard Watt engine, of a slightly earlier date. It still retained the wooden beam, which was 26in. deep and 18in. thick, but the A frame had disappeared, and a massive oak transverse beam, 28in. by 20in., supported by the side walls, carried the beam gudgeons and spring beams. The cylinder was supported on a brick pier instead of being mounted on wooden beams spanning the condenser cistern.

The chain pumps and gearing were made by John Lloyd, millwright, of Little Chapel St., Westminster. A description of the pump drawings, with instructions to the maker, exists, and is dated April 22nd, 1800. The pump barrels were 2ft. inside diam., three being 9ft. 6in. long and three 6ft. 6in. long, the ends were bell-mouthed. The chain links and saucers were of cast-iron, and the latter were packed with two turns of gaskin with the ends passed through holes in the rim: a lead ring was afterwards tried as a packing. The chain links were 18.6in. long. and the dished parts of the saucers were filled in with wood planking.

A curious point about these pumps was that they were intended to reverse and work as prime movers by the action of the water running out of the docks. One gear wheel of each pair had wooden mortice teeth, while some of the wheels fitted closely on round parts of the shafting, so that they could be moved laterally to disengage them. These were secured by a "tongue and groove," and were pinned to the shaft when in position. This is an early instance of wheels being keyed on round shafts. A copy of the bill for these pumps, dated December 31st. 1800, shows that their manufacture and erection cost £1,761 4s. 7d.

About this time Goodrich mentions the making of a model of a machine for experimenting on the comparative strength of different metals, woods, and filamentous substances.

In September, 1800, Goodrich was at Brixham surveying the ground for the laying of 2,000 ft. of 8-in. cast-iron pipe to convey fresh water. An enquiry, sent to Mr. Littlewood, of Park Furnace, Sheffield, elicited the reply that the latter was busy casting 17in. pipes for the New River Company, and could do no other work for eight weeks. The price of 8-in. pipe was 13/6 per cwt.

At about the same date some particulars are given of Bentham's floating dam or caisson for a dock gate, proposed in 1798 and made in 1799, with the method of operating it. It was built of timber and weighed 157 tons; the ballast amounting to 171 tons. It was noted that whereas the North Dock gate required 60 men to open it, and the South Dock gate 90 men, the floating dam only required 40 men to move it.

A noteworthy proposal of Sir Samuel Bentham's, made in April, 1800, was the application of the steam engine to a dredger. Although this was the first steam ladder-dredger, Boulton and Watt had supplied a 4 h.p. bell-crank engine

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to John Grimshaw, of Sunderland, for a spoon dredger, in 1796. Bentham's dredger, however, preceded Trevithick's. Enquiries for an engine were, in June, 1800, addressed to Boulton and Watt and to Mr. Whitmore, of New Hall Street, Birmingham. It is not stated who obtained the order for the engine, but the remainder of the machinery was supplied by John Lloyd, the contract price being £1,640. The dredger was designed to dig to 16ft. below the surface, and to raise 1,000 tons of soil per day of 12 hours. A 12 h.p. engine was used, modelled exactly on the lines of the Sadler table engine. It was placed in the vessel with its crankshaft parallel with the keel. The cylinder was about 20in. diam. by 48in. stroke, while the flywheel was 14ft. diam. There were 86 feet of double wrought-iron chain, and 24 plate iron buckets, of which a sketch is given. The links were four feet long and the buckets four feet wide. The chain passed round drums placed at each end of an inclined frame, which was mounted in guides so that it could be raised or lowered by a winch; the upper drum was driven from the engine by shafting and bevel wheels, a slipping clutch being provided.

A remarkable feature of this dredger, known as "the ballast heaving engine," and also of a second one built a few years later, was that the boiler had a wooden shell built up like a cistern and held together by bolts. This contained a cast-iron furnace and a convoluted wrought-iron plate flue. Sketches of this boiler are given in Goodrich's notes, and also a more complete drawing, which, however, appears from its dimensions to be a boiler for the second dredger. The boiler shell was rectangular, 9ft. 4in. long, 6ft. wide, and 6ft. 4in. high internally, the walls being of 4in. plank. The grate was arranged transversely near one end. with the fire door on one of the longer sides. The flue was 18in. square in section. Some time afterwards a new furnace and flue were fitted, with the fire door at one end and the grate running lengthwise. Goodrich stated, in 1827, that this first wooden boiler, which was made in the Dockyard, "had had its flue renewed two or three times and one new top, but the principal part lasted 20 years." The second boiler, made by contract, only lasted six years.

The first dredging vessel was a flat-bottomed double-ended lighter with a well near the middle for the bucket chain to work through. The hull was 101 ft. 6 in. long, 26 ft. 10 in. wide, and 8 ft. 8 in. deep, while it drew 5 ft. of water. The well was 18 ft. 3 in. long and 8 ft. 1 in. wide. It was ready for trial in April, 1802, and was under test for some months, but, owing to various causes, was not put into general service until June, 1803. It was able to lift two tons of soil per minute at a cost of from 1d. to 2d. per ton.

The success of the first dredger being assured, Bentham proposed, in July, 1803, to make a second one for use at Deptford. He also proposed to fit this with a Trevithick high-pressure engine, and it is recorded in the "Life of Trevithick"

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that Bentham, in August, 1803, ordered a 14-h.p. engine for Deptford Dockyard. The Greenwich explosion of a Trevithick boiler, in that year, prevented this project from being carried out, so that the second vessel was actually fitted with a duplicate of the Sadler type of engine used in the first. This second dredger, although ordered late in 1803, does not appear to have been completed until 1806. Drawings of it are preserved. It was very similar to the first, with improvements in detail.

In September, 1801, Bentham proposed to construct a "movable steam engine" which could be used for working cranes, pumping or pile-driving wherever occasion arose for its services; it was finished in August, 1802. This, however, was not the first design for a portable engine, as the Coalbrookdale sketch book contains drawings, dated 1792, of a condensing beam engine mounted on a wheeled carriage, but it is not known whether this was actually constructed.

In Bentham's machine a 6 h.p. double-acting condensing steam engine was used, having a cylinder 13½ in. diam. by 36 in. stroke, with drop valves. It was a table engine with roller crosshead guides set transversely, but in this case the crank-shaft was placed longitudinally to one side of the cylinder, with a single return connecting rod attached to an overhung crank. The crank-shaft carried a fly-wheel 6 ft. dia. and drove a winding drum through single reduction gearing, the pinion on the shaft having a dog clutch connection. The engine carriage was 16 ft. long and 5 ft. 3½ in. wide. Its rear wheels were 6 ft. 4 in. diam., and had an outside track width of 7 ft. 5½ in.; the fore wheels were 4 ft. 3 in. diam., and were arranged on a pivoted axletree. The wheel base was 10 ft.

The first boiler used with this engine was a wooden barrel, but this was replaced in March, 1805, by a rectangular wooden box. It was mounted on a separate wooden carriage 11 ft. 9½ in. long and 4 ft. 9 in. wide; its hind wheels were 5 ft. 1 in. diam., and the fore wheels were 3 ft. 0½ in. diam. Both carriages had shafts for horse haulage.

Early in 1802 it appears that the Managers of the London Company for the Manufacture of Flour, etc., were considering the rebuilding of the Albion Mills which, as is well known, had been burned down in 1791. A premium of 50 guineas was offered for the best plans submitted for a fireproof building, and in February of that year Goodrich sent in plans, which were of such merit as to enable him to share the premium with another competitor. These plans still exist and are of considerable interest. The floors of the building were to be supported on cast iron pillars with wooden connecting beams; wrought iron ties took the thrusts and no weight was carried by the side walls. Brick arches were to be turned between the wooden beams.

The machinery was to consist of three Boulton and Watt 40-h.p. double-

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acting rotative engines each driving two sets of four stones, with their dressing machinery, etc. The mill was to be capable of turning out 120,000 sacks or more per annum, but the proposal was never carried out.

Although the story of the block-making machinery at Portsmouth is comparatively well known, this paper would not be complete without some reference to it, as Goodrich's notes contain many references to this work and give some new information relative to it. Sir Samuel Bentham had intended from the first to erect such machinery in Portsmouth Dockyard and he had patented machinery for the purpose in 1793, while some of the preliminary machines had been made before 1800.

A Mr. Taylor had, in 1781, set up a block-making factory at Southampton using sawing and boring machines, but the shaping of the blocks was performed partly by saws and finished by hand. Taylor was, about 1800, the chief Admiralty contractor for blocks.

A Mr. Dunsterville also had a block factory at Plymouth which Goodrich visited and reported on in September, 1802, and some drawings of his machines exist. This machinery, although constructed mainly of wood, was evidently of a more efficient character than Taylor's, as Dunsterville's contract prices were only about one-half those paid to Taylor.

Sir Marc Isambard Brunel had considered the problem of block-making machines before he left the United States in 1799, and on February 10th, 1801, he took out a patent for improved machines for this purpose. Four machines were described: one for cutting mortises, one for sawing the edges of blocks, a lathe for turning the sides of blocks (one at a time), and one for turning, boring and grooving the "shivers" or sheaves. In the specification drawings these machines have wooden frames. Working models of them, or improvements on them, were made by Henry Maudslay, probably in the same year.

Brunel's plans were offered to Taylor and rejected by him, but when submitted to the Admiralty, in February, 1802, they were adopted on Bentham's recommendation, and Henry Maudslay was entrusted with the construction of the machines, under Brunel's superintendence. Brunel was specifically instructed to concert with Goodrich in the arrangement of the machines in the wood-mills which were under the management of the latter. The first set of machines were proceeded with at once and were completed about the middle of 1803. Brunel appears to have been paid directly for these. By an order of May 5th, 1803, Brunel was to receive an allowance of one guinea per day, while engaged on the work, plus coach hire and an extra 10 shillings per day when at Portsmouth, this allowance dated from September 16th, 1802. He was also to receive a sum equal to one year's savings, when the machinery was completed, and under this head,

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in August, 1809, he was granted £17,000. The first set of machines, for blocks from 7 in. to 10 in. long, being completed, two other sets, 4 in. to 7 in., and 10 in. to 18 in., were proceeded with, but for these Maudslay appears to have received an order directly from the Navy Board. The second set was ready in May, 1804, and the third set in May, 1805. In a paper dated October 3rd, 1805, Brunel gives the state of the wood-mills at that time. Forty machines had been completed, four were in hand at Maudslay's, and three more were projected. Even so it was not until September 4th, 1807, that he was able to inform Goodrich that, by October 15th of that year, the wood-mills would be able to supply all the blocks required by the Navy. In 1808 the number made was 130,000.

A great deal of discussion arose in the middle of the last century as to the authorship of this machinery. Some claimed the whole credit for Brunel, others for Bentham or Maudslay with some credit for Goodrich himself. The truth seems to be that while Bentham originally proposed the machinery, Brunel appeared with his improvements, chiefly for shaping the outsides of the blocks, at the opportune moment. Bentham, who was too much engaged at the time to devote himself to designing machines, saw that Brunel was just the man to do the work required, and recommended his employment. The success of the machinery was, however, undoubtedly due to the mechanical skill of Maudslay. In place of wood, he used cast-iron and hardened steel in its construction, so that it continued in use for nearly a whole century, and is believed to exist still.

The Journals record that about every three months Goodrich certified the payment of £500 to Maudslay on account of the block machinery. He also seems to have found Brunel somewhat of a nuisance at times, but in 1805 we find him congratulating himself on having effected a reconciliation between Bentham and Brunel. Amongst the papers is a press copy of Maudslay's account, which, for work done between August, 1803, and April, 1807, amounts to close on £12,000 for 39 machines, comprising saws, lathes, boring, mortising and shaping machines. It may be noted that the large mortising machine cost £1,497 5s. and the large shaping machine £1,559 5s. 4d. Small wonder that Goodrich became somewhat scared at Maudslay's mounting bill. Writing under date August 15th, 1806, he says: "Letter from Mr. Maudslay requesting a further certificate for £500, am obliged to hesitate on this head—when will there be an end of expenses and when will the work be completed; what was the estimate and what has already been paid are questions that must naturally arise. On examining what has been paid Maudslay only and advanced him by certificate, it now amounts to £12,000."

The lathe for turning iron pins is deserving of mention. It was a self-acting slide lathe with a worm-driven screw feed and automatic trip gear. The "poppitt" alone slides along the vee bed, while the slide rest travels on a

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separate flat bed at the front. The feed is stopped by dropping the worm out of engagement with its wheel. The form of tool-holder, in which a small cutter is clamped in the end of a stiff bar should also be noted. This arrangement was used on many of the machines and is shown in Brunel's patent of 1801. A large part of the machinery was driven by flat belts tightened by jockey pulleys, while in other cases friction wheels were used.

Under date September, 1802, Goodrich gives some figures for determining the power of a horse, taken from one used at the Sheerness well; these give the work done as 8,000 ft. pounds per minute. He was in the habit of making notes and sketches of ideas that occurred to him from time to time, and some of these are interesting—although there is no evidence that they were put into practice at the time. On a foolscap sheet, watermarked 1803, but upon which he had subsequently written "about 1800," there are sketches which might represent a steam driven helicopter. On the same sheet are several designs for steam boilers, one being a horizontal multitubular fire-tube boiler, and another a similar boiler with a single convoluted flue of small diameter.

Mention must here be made of the very important note, made almost certainly in 1803, and obtained from Trevithick himself. This gives the only known contemporary illustration of part of Trevithick's London coach engine of 1803.[4]

Several letters from Matthew Murray on various subjects are preserved, and the first of these, dated January 3rd, 1804, is as follows:—

"Mr. Goodrich.

"Sir,—We received your favor of the 31st ult., & can inform you that we have by us an engine compleatly fitted up of 2 Horses power, adopted for pumping water & made upon the most simple principles, by very little attention an entire Stranger may be learnt to manage it, who might be instructed while it is putting up by the Person we send for that purpose. This Engine is compleatly fitted up in a Cast Iron Cistern, & needs no other fixing than bolting upon the Foundation it is to stand on & requires no Wood work whatever, the Boiler to be set in Brick as in all other cases. The whole weight will be nearly 2 Tons, & may be conveyed very well by Land carriage at about £8 per Ton, or by water at £2. This engine is capable of pumping with a 12 Inch Pump 120 Gallons of Water 20 Ft. high pr. Minute, & more or less in proportion to the height required. The price of this Engine including the Boiler, and Door Frame & Grate Barrs for Fire Place is £175, delivered at Leeds & payable as soon as put up, we provide an experienced Engineer to put it up whose wages, board & travelling expences will be charged to you, should the above meet your

[4] Described in "Trans." Vol. I., p. 46.

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Approbation, I should be happy to attend to your early Order or give any additional Information you may require.

"I am for Fenton & Co.,
"Your most obt. Sert.,
"MATTHEW MURRAY."

Under date August 16th, 1804, is given a comparative list of prices of steam engines by three makers which is of interest:—

Boulton & Watt.

20-h.p., £1,083. 24-h.p., £1,276. 30-h.p., £1,418.	Including all the metal work and an iron beam, but not erecting or woodwork.

Mr. Trevithic.

1 horse, 120 guineas. 2 ,, 210 ,, 3 ,, 270 ,, 4 ,, 330 ,, 5 ,, 380 ,, 6 ,, 420 ,, 7 ,, 450 ,, 8 ,, 470 ,,	Including patent right and fixing but no brickwork. and rise 20 guineas for each h.p. above this.

Fenton, Murray & Wood.

20 horse, £600 25 ,, £715 30 ,, £830 35 ,, £938 40 ,, £1045	Not including boiler.

It will be noticed that Boulton & Watt's prices had increased by some 40 per cent. since 1800.

The practice of sheathing the bottoms of ships had been in use for many years, when about 1790, complaints were made about the rapid decay of some of the copper sheets. As the complaints increased, the opinion was formed that the contractors were supplying inferior copper, and Bentham proposed in April, 1800, that, as a first step towards improving it, a mill for re-manufacturing the old copper should be set up in one of the dockyards. Plans and estimates for the mills were sent to the Navy Board in June, 1803, and in August of that year, authority was given to procure the machinery. It was not, however, until September, 1805, that the mill was completed, and the rolling of sheathing commenced. The whole of the machinery for the metal mills, including rolls, hammers, and steam engine, was executed by Mr. Whitmore of Birmingham. A plan of the mill is preserved showing the general arrangement of the rolls and

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hammers; one side was intended for rolling and sheathing, while the other was to roll iron for bolts and bars. The steam engine, of 56 h.p., was a beam engine of the Watt type with a cylinder 38 in. dia. by 7 ft. stroke. A blowing cylinder 30 in. dia. and 3 ft. 8 in. stroke was placed between the crank and the centre pillars. The crank-shaft carried a fly-wheel 24 ft. dia., weighing 12.2 tons, and a double cam fixed at the end of it actuated a tilt and a forge hammer in the iron mill. A second motion shaft, driven by gearing from the first, extended both ways and drove three sets of rolls on each side. A smaller tilt hammer on the copper mill side was also driven by this shaft. A fly-wheel 22 ft. dia. and weighing 14 tons was afterwards placed on the second motion shaft.

The drawings of tilt and forge hammers show clearly their construction. It may be noticed that the tilts turn on pointed pivots, while the pivots of the forge hammers simply rest in half-round bearings.

The shears are, perhaps, of some interest, being practically enlarged hand shears. One drawing shows a hand-worked punching and shearing machine with its lever lifted by a crank pin. The punch is placed at the short end of the lever, and the shearing blades are mounted above the lever behind the fulcrum. It is noted that 19 holes per minute could be punched in ⅜ in. thick copper plate by two men at the winch handles and one to move the plate, but they could only keep up that rate for two minutes.

The cost of the metal mills engine and machinery was £6,000, and some of the chief items in Whitmore's bill may be noted. The engine itself cost £1,700, while a premium of 50 guineas was paid to fit Roberton's patent feeding mouth to the boiler for consuming smoke and saving fuel. Other items are:—

	£	s.	d.
A pair of rolls, turned (70 cwt.)	74	5	9
The main shaft (72 cwt.)	61	12	6
Fly-wheel (12.2 tons)	98	12	6
Blowing cylinder and fittings	128	19	8
Two pairs of plain rolls with housings, etc. (15 tons)	423	18	3
Iron work for tilt hammers	80	15	0
Three anvil blocks (8 tons)	113	8	0
Three beds for ditto (6¼ tons)	87	10	0
Two pairs grooved rolls	138	6	0
A pair of shears with wheel in the lever and eccentric cam wheel (on a new construction equal in value to two pairs) (weight 2½ tons)	59	14	6
A boiler fitted up complete (6 tons 17 cwt.)	274	14	0
Carriage of materials	195	15	5

Little information is available about the furnaces, save a few sketches, but two

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refining furnaces and two heating furnaces are mentioned, besides a "cupula," of which a drawing is shown.

Difficulty was experienced in obtaining suitable workmen for the metal mills, and the owners were accused of seducing men from the contractor's works by the offer of double wages. If that were really the case then the said contractors must have paid very low wages indeed, as the copper melter in the dockyard received £2 per week plus 6s. for house rent, for which he was to make one charge of two tons per day. His assistant received 27s. per week. The normal day was 12 hours, including meal-times, the men in the metal mills commencing work at 5 a.m. The superintendent of the mills received £4 per week. A gallon of small beer per day was allowed to the men at the furnaces and rolls, although Goodrich says he would have liked to have done away with this and have given money instead.

While these mills were under construction, Goodrich visited various works throughout the country, and he gives particulars of what he saw in them. On January 23rd, 1805, he went to see Mr. Cliff's iron and steel works at West Bromwich which was equipped with a 24 in. by 6 ft. steam engine lately erected by Murray of Leeds in a superior style. It had one cast-iron pillar to support the beam with an iron cross cap to carry the spring beams.

On the same date he visited Wilkinson's works at Bradley, where he observed the great reciprocating rolls used for or instead of shingling or half-blooming the iron from the puddling furnace. There were 300 tons of castings in this machine only. These rolls and one large pair of shears were worked by a 48-in. single engine. Several pairs of shears are noted with their lever ends connected directly with the engine beams. He also saw there a set of rolls fitted with a spur-wheel two-speed gear.

At the Gospel Oak Iron Works there was a steam engine with a 48-in. cylinder 6-ft. stroke, driving one blowing cylinder 6 ft. dia. by 5 ft. stroke and a second cylinder 4 ft. dia. by 2 ft. stroke, both double acting. A steam engine for a forge hammer had a 40 in. cylinder, a solid iron cam shaft, 22 in. dia., and an 18-foot fly-wheel with wooden arms. This hammer made 100 blows per minute.

Goodrich gives some particulars of Benyon's Flax Mill at Leeds, which he says was on the same plan as Marshall's, they having dissolved partnership. The mill had arched floors built between cast-iron girders which were supported on cast-iron pillars placed about 10 ft. apart. Power was obtained from a 50-h.p. engine put up by Fenton & Co. He notes that the machinery was driven from horizontal shafts 4½ in. square, making 60 revs. per minute. The lengths of shafting had pyramidal ends, coupled by boxes in halves, so that the shafts could not draw out; 6-in. or 8-in. straps were tightened upon the driving drums by two tightening rollers close to the drums.

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One or two more of Goodrich's " Ideas " of about this time may be mentioned. One of these was that a Mechanical Museum should be established in London showing nothing but working models of the most common and useful machines. Lectures were to be given and 2s. 6d. charged therefor, this price to include admission to the Museum. The machines to be minutely described in a catalogue, which was to be *lent* to the visitors. An idea which he thought might be a good subject for a patent was for the application of an easily-renewable piece of leather, wood, cork or any tough and elastic substance to the soles and heels of boots and shoes. In this he was about a century too soon. Perhaps his most curious idea was for a contrivance by which a horse driving a mill or otherwise should bring into action an automatic goad, so that if he did not pull with a certain force it should prick him until he did.

The state in which engines and boilers were worked is illustrated by a letter to Goodrich from the Superintendent of the Wood Mills, dated September 24th, 1804. He says: " I have to inform you that the Boiler of the steam engine is in a very bad plight this morning. We could not get to work till 9 o'clock. The men say that the Boiler was near or quite empty when they came to get up steam and we have been obliged to stop ten or a dozen times this Day while they raised steam."

In July, 1805, Sir Samuel Bentham received orders to proceed to Russia, to arrange for the building there of ships for the British Navy, and Goodrich was appointed to carry on the work of the Inspector General's Office during his absence. This involved much extra work for Goodrich and he several times complained that he did not know which way to turn. He seems to have worked early and late, often including Sundays, while it appears to have been a custom at the time to discuss business over the breakfast table. Such a thing as a holiday is not recorded at this early period, although on one Sunday, when at Portsmouth, he took a boat and went with Maudslay to the Isle of Wight.

At the conclusion of the paper there was an interval to inspect the Goodrich Journals, letters, drawings and documents which had been kindly lent for the occasion by the Director of the Science Museum. Illustrations, Plates I. to V., are selected from these drawings.

Discussion.

Mr. H. W. Dickinson, in moving a vote of thanks, said he thought it would be right to explain that Mr. Forward's paper was based on a bulky mass of documents preserved in the Science Museum where they had been deposited in 1875. The author, in the course of his duties, had occasion to go through these papers and had found much matter of interest; the period under discussion in the paper was one about which little is recorded, as there were then no English engineering

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papers and scarcely any scientific periodicals. Mr. Forward had hesitated to put his knowledge into the form of a paper for the Society, but the speaker had urged him to go on, as the collection of biographical matter was one of the aims of the Society; and besides, he was rescuing from oblivion the memory of a valuable public servant. The subject-matter of the paper ranged over much ground, but what appealed to the speaker was the judicial, and to his mind conclusive, way in which the author had allocated the credit for the invention and introduction of the block-making machinery at Portsmouth.

Colonel W. H. D. Clark, seconding, said Mr. Forward had given a lucid contemporary account of a little-known period of engineering history. He was glad to have Goodrich brought forward, as he was the type of man who did excellent work but never got public recognition. He thought the block-making machinery was a very good and early instance of team work; not one of the three men—Bentham, Brunel or Maudslay—alone could have carried the matter to a successful issue. Again, such co-ordination is too often spoiled at the last stage by being placed for execution in incompetent hands, but here the trio were fortunate in having Goodrich, who therefore should, in his opinion, be jointly credited with them. The speaker referred to the high standard of design shown in the drawings exhibited. He trusted that they would hear more about Goodrich.

The vote was carried by acclamation.

Mr. A. Titley said the paper was of exactly the kind that was wanted. It cast a vast number of sidelights on engineering, in particular on the construction of steam engines of the period.

Mr. C. E. Greener was struck by the details preserved in the Goodrich Journal as to manufacturing costs, which were so difficult to come by, yet so useful to anyone at the present day, for comparison. Goodrich was a good example of the Government official, for he never went anywhere without picking up information.

Mr. W. A. Young said that as Whitmore of Birmingham had been referred to, it might be of interest to members to know that a trade catalogue of his was preserved at the Victoria and Albert Museum.

Mr. G. F. Tyas said that Sadler's engine was referred to in Farey's "Steam Engine," and it was, in his opinion, the prototype of Maudslay's table engine. The paper brought out clearly what great rivals of Boulton & Watt were Fenton, Murray and Wood of Leeds.

Mr. Rhys Jenkins said the Society was to be congratulated upon the paper. The period under review was important but quite obscure, and such documents as these were our only sources of information now to be hoped for. Mention having been made of boilers with wooden shells, he might state that they were not uncommon, and with the low pressures then in use there was no reason against them;

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the experience with them, however, was that they always went at the water-line. The author's summing-up of the merits of those concerned in the block-making machinery was admirable. The name "rigger" was a well-known one for a pulley in the south of England. They had heard a little about Grimshaw and rope-making at Sunderland; he hoped to hear something more about this remarkable man.

Mr. E. W. Hulme enquired if any corroborative evidence as to Goodrich's history had been obtained from the Record Office.

Mr. Lancaster Burne said he believed that wooden boilers, externally fired, had been used in America.

The Author, in reply, said that he had not searched at the Record Office, but intended to do so. The paper certainly did not give much information about Goodrich personally, but it might be gathered from his papers that he was a fair dealing and generous man, very cautious in making important decisions. He appears to have been well liked by those with whom he came in contact. Nothing is known of his early training, but Lady Bentham's writings suggested that his practical experience was small when he was first appointed as draughtsman. His Journals contain a great deal of matter that was not engineering. The Author was unable to give any further evidence as to the use of wooden boilers. The Journals and papers contain a large amount of matter relating to Grimshaw's rope-making machinery and to his litigation with Huddart, and this would be of great use to anyone investigating Grimshaw's work. He might mention that Goodrich asked for some remuneration for acting as deputy during Bentham's absence in Russia, but he notes in his papers that he received nothing but thanks.

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Notes on the Early History of Steel Making in England.

By Rhys Jenkins.

(*Read at the Iron and Steel Institute, Westminster, Nov. 29th, 1922.*)

The history of the production of steel in England before Huntsman's invention of cast steel, say about 1750, does not seem to have been the subject of research, and remains obscure. The notes now presented will throw some light, at any rate, on the beginnings of one of our great industries.

That steel was being produced in England in the time of Queen Elizabeth is well known. William Harrison, in "A Description of England," printed in Holinshed's Chronicle, 1577, writes:—

"As for our steele, it is not so good for edge-tools as that of Cullen (i.e. Cologne), and yet the one is often sold for the other, and like tale used in both, that is to saie, thirtie gads to the sheffe, and six sheffes to the burden."[1]

This account makes it clear that although our makers were producing steel, yet they had not succeeded with the higher grades, and there was considerable importation then, which continued long afterwards. This importation was made, by Queen Elizabeth, the subjects of grants of monopoly to Beale, Annesley and others. In a discussion on monopolies in the House of Commons in 1601, it was stated that the monopoly of steel, by doubling the price, had thrown two thousand workers out of employment.

When steel was first made in this country it is impossible to state. Perhaps we may venture to say that its manufacture is as old as that of iron. In the production of wrought iron direct from the ore, the aim was to produce a doughy mass without fusion, and to keep this mass in the hearth and in contact with the fuel for as short a time as possible. If, through some defect in working, improper disposition of the tuyers, low quality of fuel, or some peculiarity in the ore, the iron had to be retained a longer time in the hearth, it took up more or less carbon, and a steely iron, a mass part steel and part iron, or even steel, was produced.

On the other hand, these features, which had been objectionable for the production of wrought iron, became desirable when it was sought to produce steel; for instance, the tuyers, instead of being strongly inclined, were set more close to the horizontal. A writer on iron in 1804, referring to the Catalan forge, states

[1] The second edition of Holinshed, 1587, gives "twelve sheffes to the burden."

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that the mass is usually composed of steel and iron, but that it is not regularly so, and that the workmen ascribe the irregularity to chance or to the quality of the ore. The same author remarks that in Styria and Carinthia the operation of producing iron is performed in 1½ hours, whereas the production of steel takes five hours.[2]

After the introduction of the blast furnace and the finery for converting the cast into wrought iron, the conversion process could be worked in such a manner that the carbon was not eliminated to the full extent.

The earliest definite mention of a works for the production of steel that the author has found is in 1523, when we find that John Glande held a tenement called a "Forge of Steele" in Ashdown Forest, Sussex. In 1525 this forge came into the hands of John Bowley, who still held it in 1548.[3]

Then in 1565 Sir Henry Sidney, of Penshurst, Kent, the father of the better-known Sir Philip Sidney, was in the field as a steel-maker. It is unlikely that he can have taken any active interest in the business himself, for from the year 1556 until his death in 1586 his official duties as Lord Deputy of Ireland and Lord President of Wales led to his living the greater part of his life away from his home in Kent.

After the Dissolution of the Monasteries, the possessions of the Abbey of Robertsbridge, Sussex, came into the hands of Sir William Sidney, the father of Sir Henry. In 1541, he erected an iron furnace and a forge at Robertsbridge, and in the following year another furnace at Panyngridge in the same neighbourhood. At the death of Sir William the property passed to his son. In 1564, an agent of Sir Henry engaged at Antwerp certain "Duchmen," Frolycke and Bowde (or Budde), to come over to England and start the manufacture of steel at Robertsbridge. Apparently these men were not satisfied that the local iron was suitable for the purpose, and a furnace was taken in Glamorganshire, near Cardiff. John Bowde and three other Dutchmen were sent there in June, 1565, and in December of the same year 20 tons of "plats" were shipped from Cardiff to Rye. Before September of the next year 74 firkins of steel had been shipped to London and to Wales.

These Dutchmen were no doubt Germans from somewhere in the neighbourhood of Cologne, and the process followed would be the finery process, for which the iron from the blast furnace, instead of being cast into sows or pigs, was cast into thin flat bars here called "plats." The steel was sold in firkins. To produce 57 firkins required 27½ tons of plats. It would seem that one Edmund Roberts, of Hawkhurst, was associated with Sir Henry Sidney in this enterprise.[a]

[2] [Manson] Traité du fer et de l'acier, 1804, pp. 158, 38*n*.

[3] Minister's Accounts, Bundle 445, No. 7185, quoted in the Victoria County History of Sussex.

[a] MSS. of Lord de l'Isle and Dudley at Penshurst. See Appendix, p. 33.

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One judges that the Dutchmen were not altogether liked in the neighbourhood of Robertsbridge, for we find that in March, 1567, the Lords of the Privy Council caused a letter to be sent to certain Justices of the Peace for the County of Sussex, stating that complaint had been made that" John Sharpe, of Robersbridge or nere thereabouts, naming himself a master of fence, hath of late not only beaten diverse Duchemen which hath been employed in that county by the procurement of Sir Henry Sydney, Knight of Th' order [i.e. of the Garter] and Lord Deputye of the realme of Ireland, for the making of steale, but also hath used suche unfitting wordes against them as is not to be suffered." The Justices are required to take the matter up and see that " the said Duchemen may have no further juste cause of complainte."[4]

We do not hear anything further of the Robertsbridge works till 1609, when it appears that John Hawes farmed the estate, upon which there was " a capital mansion - - also various buildings for steel makers, wherein were eight steel forges - - also one great gate-house called the West Gate, built of lime and stone, and covered with tile, used in part as a dove house and in part for the steel makers; also a great gate called the East Gate employed as a storehouse for iron, with a house attached to it for James Lamaye, the hammerman."[5] This is the last account we have of this works, and its terms do not allow us to say definitely that the establishment was still in operation. The fact that the hammerman lived on the spot suggests that if idle it had not been so very long. The circumstances that the West Gatehouse was used in part as a dovehouse and in part for the steel-makers is interesting.

Another point may be mentioned about Sir Henry Sidney:—In 1566 he was applying in Parliament for an Act for " making steel and plates for armour within the realme." His Bill got through the House of Commons, but did not pass the House of Lords; its provisions have not come down to us.

Another site of steel forges in Sussex was Warbleton; about a mile south of the village, one may still pass from Hammer Lane into Steel Forge Wood. The date at which this works was carried on is not known.

Our next note concerns the invention of the cementation process.

In 1614, William Ellyott and Mathias Meysey obtained a patent for converting iron into steel " by means of a reverberatorie furnace with potts luted or closed to be putt therein containing in them certaine quantities of iron with other substances, mixtures and ingredients, which being in the said furnace brought to a proportion of heate doth make or convert the same iron into steele, which steele

[4] Acts of the Privy Council, Vol. 7, p. 333.

[5] Rousse, Beauties and Antiquities of Sussex, 2nd ed., 1827, p. 112, quoting a document in the possession of Sir Godfrey Webster, the then owner of the Manor.

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with other heat temperatures and hammerings to be afterwards given to the same doth make it good and fitt for the uses before mentioned."[6]

There can be no doubt that the cementation process is here described. The patent recites that there is a great demand for steel in England and Ireland for making armour and weapons, scythes, knives, edge tools for carpenters, masons, etc., that the amount now made in the Kingdoms is small in comparison and the steel is of such inferior quality that it is not much used for the purposes mentioned, so that we are forced to rely upon foreign material. Ellyott and Meysey, at the great costs and charges of themselves and their friends, and by the painful labours and endeavours of themselves and others set at work and employed by them, have lately found out and attained unto a certain new way and means never before in known use and practise in England or Ireland whereby iron may be converted into good steel fit for all the uses before mentioned for which the steel ordinarily brought from the parts beyond the seas has been commonly used. The patent was for the term of twenty-one years, at a yearly rent of £10.

From the terms of the second clause in the recital just quoted, the Author is led to think that the invention was not an importation from abroad, but of native origin, and that it originated with Ellyott and Meysey. They were both natives of this country, and there is no suggestion that they employed foreign workmen. A few years later we find them objecting to the grant of another patent for steel, and alleging that Palmer, one of the petitioners, was a Dutchman, which appears to have been the fact. Now had the invention been of foreign origin, had either of the inventors not been natives, or even had foreign servants been employed, Palmer and his friends could hardly have refrained from seizing upon the fact.

It seems to have been recognised generally that the cementation process had taken root in England before it was used to any extent on the Continent, but it was not known whether it had originated in this country or not, nor to what date it went back. This patent must be held to settle both questions. It is not necessary here to lay stress on the great industrial importance of the invention.

What " other substances, mixtures and ingredients " were put into the pots with the iron is not known. It is to be remembered that the metallurgists of those days had not arrived at the knowledge that the addition of carbon was all that was required. The prevailing idea seems to have been that steel was a purer and more compact form of the metal than wrought iron. By 1693 Dr. Lister had arrived at the conclusion that " iron of itself, however oft soever it is purged and refined, will never become steel," although of iron so purged and refined the best steel doubtless may be made.[7] Most probably the materials were of the same nature as those used for case-hardening, i.e. mainly organic substances, such as the horns and

[6] Public Record Office, Patent Roll, 12 James I., Part I., No. 15.
[7] Philosophical Transactions, No. 203, p. 865.

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hoofs of cattle, old leather, etc. Case-hardening is described by Theophilus, the monk, in the 11th century,[8] and Plot refers to it as being a common process in his day, say seventy years after the date of the patent,[9] and the presumption is that it was in use at the date of Ellyott and Meysey's invention, but the writer has no definite evidence to this effect.

It may be, then, that the invention was a development of the case-hardening process, possibly in the light of knowledge acquired from the manufacture of brass. The cementation process had been applied before this to the production of brass from sheet copper and calamine, and it is known that it was being carried on in England ten years before the date of the patent, but there is some doubt whether the industry was still in existence.

It is a matter for regret that nothing is known of the inventors, Ellyott and Meysey, beyond the record of their inventions. Their works were probably situated in London, then no doubt the largest steel-consuming town in the kingdom, and where, according to a contemporary writer, "at this day the best and finest knives in the world are made."[10]

Ellyott and Meysey succeeded in producing steel, and in 1616 they obtained another patent for carrying out the main invention with pit coal instead of wood. This patent gave them extended privileges; they were granted the sole right of exporting steel, and the importation of foreign steel (except in manufactured articles, plates for armour, sword-blades, etc.) was prohibited upon pain of forfeiture. The patentees were empowered to examine all ships and parcels of steel arriving at any port or haven, and to open any chests, packs, or other bulk whatsoever wherein any steel shall be suspected to be concealed. To compensate for the loss of the Customs duty on the imported material, they undertook to pay the King £293 16s. 8d. per annum (representing the average receipts for three years),

[8] An essay upon various arts by Theophilus, called also Rugerus, priest and monk. Ed. Robert Hendrie, 1847. Theophilus, after instructing us how to temper steel files, goes on to deal with small files made from soft iron, "molli ferro"; he says, anoint them with the grease of an old hog, and bind them round with small straps cut from the skin of the buck goat, and tie them with flaxen thread. Afterwards cover them one by one with beaten clay, and leave the handles bare. And when they are dry place them in the fire, and blow strongly and the skin is burned; and quickly taking them from the clay, extinguish them equally in water, and, being taken out, you will dry them at the fire. (Book iii. Cap 19.)

[9] Plot, R. The Natural History of Staffordshire, 1686, p. 373.

[10] Howes' Stow's Annals, 1615. About a hundred years later Ephraim How, another Londoner, is said to make the best knife blades in England (Harris: History of Kent, 1719, p. 359). It is to be borne in mind that the centralisation or localisation of industries such as we have to-day is comparatively modern. At about the same date as Ephraim How was said to make the best knife blades in England, another writer was saying that Oxford had the reputation of making the best knives in England (Plot, R., Oxfordshire, 1705), and later on in the century, in 1776 and 1779, respectively, we find such unlikely places as Salisbury, and Woodstock, Oxfordshire, described as famous for steelwork. At the latter place, highly ornamental scissors were made. (Diary of Mrs. Philip Lybbe Powis, 1899.)

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and to increase the rent by £50. On the other hand, they were to supply their steel to the public at prices not exceeding sixpence the pound.[11]

In 1617, D. Powell, A. Palmer and G. More put in a petition for a patent for making steel; this was opposed by Ellyott and Meysey who, in their petition to the Privy Council, state that several examinations of their steel, both before and after the grant of their patent showed that it was very serviceable, that they had gone to considerable charges in erecting works, and now attempts were being made to discredit their steel. Ellyott and Meysey succeeded in having the patent stopped, only to find themselves confronted with more powerful rivals. In May, 1618, they complained to the Privy Council that "contrary to their privilege granted by His Majesty under the Great Seale for the sole making of steele after their Invention, one Robert ffloud, Doctor of Physicke, hath entertained a ffrenchman to practice the same, hath put up ffurnaces, and is now in work notwithstanding his Maties inhibition in the L^tre Patent."

The clause prohibiting the importation of foreign steel was one of great importance, and the patentees appear to have taken steps to enforce it as soon as it became operative. As, however, they had not succeeded in making the higher qualities of steel, complaint arose. In 1618, the scythe-makers and gunmakers declared that they could get no steel fit for their use. In the following year, the case is put more emphatically, certain cutlers, gunmakers, blacksmiths and locksmiths declaring that the steel of the patentees is worthless, and requesting permission to use foreign steel.

By this date, the patent had been transferred to Sir Basil Brooke, who was one of the farmers of the King's ironworks in the Forest of Dean, and a man of considerable influence. At any rate, the Privy Council turned a deaf ear to the users of steel; but more powerful opposition soon arose. Under a treaty between England and the Low Countries, there was to be free importation of commodities on both sides. The prohibition of the importation of steel struck a blow at the trade of the Dutch merchants, their representatives in this country entered a protest, and the patent was revoked. Sir Basil Brooke then petitioned for the grant of a patent for the manufacture of steel according to the invention, without the prohibition of importation.

In the meantime, Dr. Flood, who occupied a prominent position in London, had been working on his own account to upset Brooke's patent. He had made an offer to pay the King £5,000 for permission to make steel, and had caused to be put in a number of certificates, by artificers using steel, to show the badness of Brooke's steel and the excellence of that made by the Frenchman Rochier. He now, 30th May, 1620, petitioned against the new grant to Brooke; he had brought

[11] Public Record Office, Patent Roll, 14 James I., Part 13, No. 12.

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over from foreign parts certain persons expert and skilful in the making of steel, intending to employ them in England, but his good intentions are like to be frustrated by the new patent now sought for. The matter was considered in the Privy Council on September 27th, 1620, and we read in the Register under that date: " Whereas the business concerning the makinge of Steele within the Kingdome hath been of late often debated at the Board, and the patent formerly graunted to certaine persons for the sole makeing of steele and prohibiting the importation of anie from forraine parts recalled and taken in, as well in respect of the insufficiencie and badness of steele made by these patentees as for other reasons of state expressed in former orders of the Board. And forasmuch as Robert Fludd, Doctor of Phisick, hath at his great charge drawn over hither from forraine parts certain persons and amongst others one John Rochier a ffrenchman skillful and expert in makeing steele and being an humble suitor for a patent to sett them on worke in that mystery for the good of the publicke did this day offer to the Board a certificate under the hands of manie Cutlers, Blacksmyths, Locksmyths and other Artificers workeing in steele, that the steele made by the said Rochier is very serviceable, good and sufficient. And Doctor Fludd further undertakinge to make as good Steele as anie is made in forraine parts and to vent the same at easier and cheaper rates, than the outlandish Steele. That they will waste noe wood but only make it of Pitt Coale. That they desire no Barr of importation more than what the goodnes and cheapnes of their stuff shall occasion, and thirdly that his Matie shall have a third part of the profitt arysing thereby."

King James was present at this meeting of the Council, and no doubt the offer of a third of the profits appealed to him. At any rate, it was decided to grant a patent to Fludd and Rochier " upon security to be first given as well for the makeing of good and serviceable steele as for conferring the third part of the profitt to his Matie."

The patentees seem to have got to work and to have produced steel, but whether there were any profits to divide is doubtful. Rochier died five years later. His widow alleged that he died of grief at being defrauded of the third part of the benefit of his patent by Dr. Fludd and Caleb Rawlins.[12] With the death of Rochier the project probably came to an end. It is somewhat remarkable that it should have come to us from France, for at this period it would seem that French steel was no better than our own.

In Piedmont, according to a work published fifty years later,[13] steel was made by taking small pieces of iron and powdered charcoal, placing the iron and the charcoal in layers in a large crucible on the top of which a cover was luted, and

[12] Hist. MSS. Commission, Coke MSS., i., 197; 1625, May 23. Notes of 2nd Audience at Whitehall.

[13] Felibien, A. Des Principes de l'Architecture, etc., 1766.

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then inserting the crucible in a furnace. It is possible that this process may have been in use long before, and it may have been that which Rochier brought to England. It will be observed that he professed to use pit coal as fuel. The account does not state whether the iron was fused or not. If it was fused, the process was similar to that used for the production of wootz steel; if not, it was the cementation process.

The idea that Dr. Fludd's undertaking came to an end with the death of Rochier is confirmed by the fact that he did not oppose the grant of a patent in 1626 to Richard, Lord Dacre, Thomas Letsome and Nicholas Page of a privilege for making steel by the way invented and perfected by Letsome at the charge of Lord Dacre and with the assistance of Page. Thomas Letsome was a merchant tailor of London. Richard Lennard, Lord Dacre of the South, was the owner of iron-works in Sussex, where possibly the invention was worked; he died in 1630, leaving a son, a minor. It is probable that the project was then abandoned.

While we have no express contemporary record of the fact, it seems to be the case that Sir Basil Brooke took the invention of Ellyott and Meysey down to Gloucestershire and started the production of steel by cementation at his iron works in the Forest of Dean, and that it was from there that it spread to other parts of the country. In 1635, when the grant of a new lease for the Forest of Dean works was under consideration he put forward the claim that he had settled the new invention of making steel in this kingdom.[14] Certainly his name became well known in connection with this product. Fuller, in his "Worthies," in dealing with Gloucestershire, in 1662, fifteen or sixteen years after Brooke's death, refers to him as "the great steele-maker in this county,"[15] and, at about the same date he is mentioned as a steel-maker in proceedings before the Privy Council relating to another patent for steel. In 1693, as we shall see later, steel was still being made in Gloucestershire.

We come now to the first of our notes dealing with the production of steel in Yorkshire.

During the Commonwealth, Charles Tucker or Tooker of Rotherham, upon the allegation that he and one Morostey had discovered a new process of manufacture, obtained from Cromwell a patent for the sole making of steel within the kingdom. In 1662, soon after the Restoration, the "cutlers sythsmiths and many of ye artificers of hard wares in Halomeshire in ye county of York" petitioned against the grant of a new patent to him. They stated that Tucker's only object was to monopolise the making of steel, and so to compel the users to buy

[14] State Papers Dom. Charles I.

[15] Possibly Fuller's observations express fairly the standard to which English steel had attained in Brooke's time; he states that it is "useful for the making of English knives, sythes, scissors, shears, etc., but fine edges cannot be made thereof, as lancets for letting of blood, incision knives, dissecting knives, razors, etc."

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steel of him and at his own price; moreover, he had already acquired a great estate by the former patent. Forty years before Sir Basil Brooke, Sir William Bowes and others had made as good if not better merchantable steel, and since the Restoration, George Harrison and George Arderon had done the same, and at far cheaper rates than Tucker. It was decided by the Council that no patent be issued to Tucker, or, if a grant had already been made, that it became void.[16]

However, the monopoly was too valuable for Tucker to relinquish without a further effort. He persuaded Sir John Reresby and Sir Thomas Strickland to apply for a patent and agreed to pay them £100 a year for the use of it. This patent was granted in 1665 (No. 146), and at the beginning of the following year there came before the Council the petition "of the makers of steele, cutlers, scissermakers and others ye makers of edge tools in Hallamshire in the County of York," praying that the patent be made void and that no monopoly of making steel may be admitted.[17] They recite the facts as in the earlier petition, adding, however, that Tucker was an active officer in the late wars against His Majesty, and that he obtained his patent by the favour of Lambert. They point out that neither Reresby nor Strickland were experienced in the art, "or ever publiquely did exercise the same" and state: "That on the 14th and 15th of January last, the said Sir John Reresby did cause a Bayliff of the liberty to publish a Paper at two severall market Townes, wherein he declared the late Letters Patent he had obtayned were procured in favour of the said Tucker, and that Tucker is to pay one hundred pounds per annum to Sir John Reresby for a Deputation for the sole making of steele in this kingdome."

The matter was referred to the Solicitor General with instructions to hear both parties. What happened afterwards does not appear, probably when Reresby and Strickland understood all the facts of the case, they threw up the patent. Reresby was a prominent Royalist and High Sheriff of Yorkshire. George Harrison and George Arderon, referred to above, were probably making steel in or near Sheffield.

There is no hint as to the nature of Tucker's invention. The writer is inclined to think that he, or Morostey for him, had acquired a knowledge of the cementation process from the Forest of Dean works, and that he had no new invention, or, that if he had anything new, it was a mere matter of detail. If this view be correct, then we may take it that the introduction of the cementation process into Yorkshire took place about the year 1650.

Another inventor of this period, who must not be overlooked is Prince Rupert. He had a method of converting into steel all manner of edge tools, etc.,

[16] Public Record Office. Registers of the Privy Council, 1662, April 23rd.
[17] Public Record Office. Registers of the Privy Council, 1666, February 13th.

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formed of soft iron, but we do not know what his method was, or whether it was applied in practice. Possible it was merely a case-hardening process.

Before the year 1686, the cementation process had been established at Kingswinford in Staffordshire. Plot tells us that John Heydon at the Tile-house at Bromley in that parish converted bars of iron into steel, and that he used not English but Spanish or "Swedish" bars. Plot's description of the process, the earliest known to the writer, is interesting although, as will be seen, it omits one essential feature—the material put into the "coffins" with the iron. Plot indeed recognised that it was incomplete, and that the process as described was simply one of annealing, and says that he suspects there was something else "besides what John Heydon was willing to impart." Heydon, he says, "has a round oven built of brick like a baker's at the top, having a grate in the bottom near the middle about a foot and a half or two foot wide, where he lays the coal; on each side whereof, and at the end beyond it, he lays his iron enclosed in coffins made of Amblecot clay to keep it from melting; the coffins being proportion'd to the barrs of iron, which are broken into lengths of between 3 and 4, or 4 and 5 foot long; the longest being placed at the end of the oven, and the shortest on each side; each coffin containing about half a ton of iron. When the fire is put to it, it is constantly tended day and night till the operation is perform'd, which according to the goodness or badness of the coal, is done in a longer or a shorter time, sometimes in three days and three nights, other times in four, and sometimes not under a week's time, the critical minute in which the operation is finisht being the great secret of the art of making iron into steel, which being done, they cut it into narrower barrs about half an inch over and then break it into short pieces of an inch or two inches long, call'd gadds, whereby the buyers may see whether it be good or bad (for there may be both in the same bar), otherwise they care not to buy it."[18]

Steel, it will be noticed, was still being sold in "gadds," as it was in the time of Queen Elizabeth but now the imported article was coming in in the form of small square bars 7 or 8 feet long as well. Plot's explanation of the reason why the metal was broken up into such short lengths is no doubt sound, but the origin of this plan must have been to enable the makers to see the fracture and thus to send out a satisfactory article. The writer is of opinion that it was not usual to make the gadds quite so short as stated by Plot.

By the close of the seventeenth century, the English steel-makers were turning out a better article than that recorded by Harrison in 1577. Moxon says that the steels that are in general use here in England are the English steel, the Swedish, the Spanish and the Venice steel, there is good and bad of each of these, but one

[18] Plot, R. The Natural History of Staffordshire, 1686, p. 374.

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may be better suited for a particular purpose than another. "The English steel," he says "is made in several places in England, as in Yorkshire, Gloucestershire, Sussex, the Wild of Kent, &c. But the best is made about the Forest of Dean, it breaks fiery, with somewhat a coarse grain. But if it be well wrought, and proves sound it makes good edge tools, files and punches. It will work well at the forge and take a good heat."[19]

These notes can hardly be concluded without a reference to steel-making in the neighbourhood of Newcastle-upon-Tyne, and the introduction of shear steel. Sir Ambrose Crowley, who was an alderman and carried on an extensive business as an ironmonger in London, in 1682 established iron works at Sunderland, employing workmen from Liége and elsewhere on the Continent. In 1690 he moved his works to Swalwell and Winlaton, near Newcastle. At his Winlaton works in 1698, he was making among a great variety of smithwork, augers, edge-tools, and files. The writer is not aware of any evidence that Crowley was at that date producing the steel from which these articles are made. But if he was not producing steel then, he must have started doing so soon after. At any rate, in 1712, the lading of the ship "Anne" included "10 whole faggots of steel, 6 half faggots of steel, 10 Bundles of Rod Steel," and "20 whole bars of blistered steel" from the Swalwell works.[20]

It is worthy of notice that when Crowley moved to Swalwell a factory had just been established at Shotley Bridge on the Derwent, eight miles away, for the manufacture of "hollow sword blades." This factory was manned by German workmen, mainly from Solingen, and it is presumed that steel was made on the spot, and at first from local ores. Now towards the end of 1702, this works was closed down; it remained closed for about a year only, but no doubt the men dispersed—we know that one of them returned to Germany. It may be that some of these men found employment close at hand with Crowley, and that this date marks the start of steel-making at Swalwell.

However that may be, Crowley's venture is specially interesting in that the introduction of the manufacture of shear steel is ascribed to him. We appear to have been importing large quantities of "German steel," and Crowley, it is said, brought in German workmen conversant with its manufacture."[21] The date of this is not known, but it will be noted that faggots of steel formed part of the ship's lading in 1712. Jars, who visited Newcastle in 1765, states that steel was sold in various forms: (a) as it leaves the cementation furnace (blister steel), (b) blister steel forged under the hammer (common steel). This was the form in which the greater part of the product was sold; it was sent in large quantities

[19] Moxon. Mechanick Exercises, 2nd ed., 1693, p. 54.
[20] The Victoria County History of Durham. Vol. II., p. 283.
[21] Manufactures in Metal (Lardner's Cabinet Cyclopaedia). 1831. Vol. I., p. 233.

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to Sheffield, Birmingham and other places. (c) Shear steel formed by faggoting bars of blister steel. Jars calls this "acier d'Allemagne" and remarks that the process was the same as that used in Styria, i.e., the process of faggoting and doubling, except that in Styria it was used not with cement steel but with natural or direct steel.[22]

At the date of Jars's visit there were a number of cementation furnaces in the neighbourhood of Newcastle. Swedish iron alone was used, many experiments had, he says, been made with English iron, but it had proved impossible to obtain steel of the same quality.

As we have seen Swedish iron was in use in Staffordshire in 1686, but its application for steel-making in this country goes further back than that; in 1631, certain Aldermen of London, at the request of the Privy Council, were investigating the quantity of steel that could be produced from Swedish iron.[23]

Jars does not mention the manufacture of shear steel at Sheffield, but a couple of years after his visit, i.e., in 1767, the process was brought there by a man named Eltringham from the Newcastle district.[24]

The next great step in steel manufacture in England was the introduction of cast-steel by Benjamin Huntsman, and this is a convenient point at which to leave the subject as his work has been dealt with by Smiles in his "Industrial Biography," and later by Sir Robert Hadfield before the Iron and Steel Institute in 1894.

The Author read his paper in abstract premising that it had been suggested by previous writers that the cementation process was an English invention; he thought that the evidence brought forward in his paper now put the matter beyond doubt. Mimeographed copies of the paper were available at the meeting.

Discussion.

The President, Mr. Loughnan Pendred, said that the paper was a fascinating one and the Author had decidedly proved his case. It was flattering to think that, to the puddling and the Bessemer process, they might now add the cementation process as being of English origin. On the President's motion, a vote of thanks to the Author was carried by acclamation.

Sir Robert Hadfield said that anyone who had been in Egypt must have been struck by the extent of the carving to be seen on hard stone such as syenite. He was satisfied that it could only have been done by steel tools. He was quite sure that 2,000 years ago the art of steel-making was known to the Scythians. There was a piece of steel at the British Museum known to be about that age; it was

[22] Jars, Voyages Métallurgiques, Vol. I.
[23] Remembrancia, p. 528.
[24] Jeans, J. S. Steel, 1880, p. 13.

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not quite hard enough to scratch glass. Near Colombo in Ceylon there had been a good deal of steel made and in the Museum there a piece of undoubted crucible steel was preserved. It was the difficulties in production that prevented the advance of the process before Huntsman's time.

Mr. F. W. Harbord said that iron from the bloomary was no doubt graded according as it was found to be hard or soft. The technique of the direct process was known much earlier in the East than in the West. In the cementation process the author had said that the mixture and ingredients were not known, but he could think of nothing else than that soft iron was imbedded in carbonaceous matter—animal charcoal, etc.—much as is done at present in fact.

Col. N. T. Belaiew said he had spent some time in enquiring into the early history of steel and found that the crucible process originated in India whence it came to Europe. His researches in damascening went to show that this was really of the nature of cement steel and that it was known 2,000 or 1,500 years ago. While the ductility was great the carbon content was 1.8 to 2 per cent. The steel did not originate in Damascus but was brought thither by Persians and Arabs. There was evidence that the cakes of steel presented to Alexander the Great were of this variety. Certainly a trade existed between Damascus and Rome. In the 9th and 10th centuries a large amount was imported from the Persian border to Russia (Kieff). By the Black Sea the trade reached Sicily and thus the Mediterranean area. By the Dneiper and the natural waterways, the steel reached the Norse peoples. The Danes who invaded England in the 10th and 11th centuries possibly owed their superiority to weapons made of this steel. He had spent some time in the West country studying Norman churches which he found built in Norse measures, which in turn were akin to Russian, the suggestion being that the culture had spread by that route. The speaker was of opinion that the oldest processes in metallurgy were derived from the East.

Mr. H. G. Graves mentioned that wootz steel in India was made in cakes about 5 in. diameter and 1½ in. thick. He had looked up one point about steel, and that was the date when the influence of carbon content on hardness was realized. About 1750 hardness was believed to be due to contained salts and to sulphur. In 1791 the rôle played by carbon was beginning to be understood; in 1795 is was practically accepted; after 1800 it was common knowledge.

Mr. E. W. Hulme said he had been trying to unravel some of the names which appeared in the 14th century accounts of the Tudely Ironworks, Kent.[25] *Gorsuma,* a Norse word meaning "treasure" was used in the sense of money paid in advance to workmen; this suggested that these workmen came originally from Scandinavia. The history of the word cementation, apart from its applica-

[25] Giuseppi, Archaeologia LXIV.

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tion to steel-making, should be looked up. The first appearance known to him was in connection with the metallurgy of gold in Platt's "Jewell House of Art and Nature," 1594. The Meyseys were a well-known Anglo-Norman family settled in Gloucestershire and in the city of Worcester. When there are two persons concerned in a patent, one will generally be found to be the financier and the other the technical man, and he would therefore suggest that Ellyott was the latter or "true inventor." The same reasoning led him to infer that Morossi or Morostay was an Italian and Tucker the promoter of the invention, which may have been the Venetian process of steel making.

Another point was the crucibles: there was a close connection, he was sure, between the closing of the pots in glass manufacture and the manufacture of crucible steel. The steel-workers were guided by the precedent set by the glass-makers. Finally he would class Cologne steel as French steel.

Mr. J. W. Hall mentioned that in Spencer "Book of Industries of the Tyne," Protestant refugees at Shotley Bridge in 1628 were alluded to. There was a house there with a German inscription and the date 1691. He might mention that blister steel made from Staffordshire bars showed small blisters, while Swedish bars showed large blisters. Puddled steel was later than 1809.

The President mentioned that the term gad was used for a wedge in mining; the connection was obvious.

Mr. Jenkins, in reply, said he had confined himself in his paper to a limited period and to this country. His paper left ample room for future work, but as it appeared from the remarks of some of the speakers that a certain amount of misconception existed as to the nature of the processes for the production of natural or native steel, i.e., the processes in use in England before the cementation process, he would amplify the brief account of these processes given in the paper.[26] The word "gad" meant, broadly, a short stumpy piece of metal; it was first used, to the author's knowledge, in the finery process. These small pieces were no doubt quite large enough for most of the purposes to which steel was applied in early days. Mr. Graves and Colonel Belaiew had made it clear that before the end of the 18th century it was recognised that steel was a compound of iron and carbon. That is to say, recognised by scientific men, for it is doubtful whether the steel-maker had adopted this view so early; Jacques Charles de Manson, general of artillery in the French Army, in his "Traité du fer et de l'acier," 1804, rejects this view altogether and holds that steel is merely a dense form of iron. In reference to Mr. Hulme's remarks, the earliest use of the term "cementation" in English and as applied to steel-making is in "A Dictionary of Arts and Sciences, by a Society of Gentlemen," 1755; but as Mr. Hulme

[26] This has been done. [Ed.]

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pointed out, the word in other connections is much older. As applied to the parting of gold and silver it is used by Agricola, and earlier still by Geber; Theophilus describes the process, but does not use the word. Cologne steel was so known because it was shipped at Cologne; it was made at Solingen, Siegen, and other places in that region and there is, so far as the author is aware, no indication of French influence on its production. The Shotley Bridge works mentioned by Mr. Hall is referred to in the paper at p. 26. The undertaking seems to date from 1688, and in 1689, nineteen or twenty workmen, with their families, were brought from Germany to Shotley Bridge.

CORRESPONDENCE.

Professor C. H. Desch wrote that Mr. Jenkins's researches have proved to be of extraordinary interest, and will be found particularly valuable to Sheffield metallurgists. The cementation process, with which Sheffield has been so intimately connected, has hitherto been traced only to Newcastle and is usually supposed to have come to this country from Germany. Its origin has been involved in mystery, and the earliest descriptions known represent it as a process already established and perfected. The new evidence makes it clear that it is older still, and that in all probability it is of English origin. There is one point on which perhaps Mr. Jenkins could give some further information. The account of the cementation process given by Réaumur in 1722 shows a furnace which is the same in principle as the furnace of the present day, but is quite different in appearance, being almost cubical, whilst the furnaces erected in Sheffield by Huntsman in 1750 are of the familiar type with outer shaft like a pottery kiln. It would be interesting to know when the latter furnace with its domed roof and external cone, was introduced, and whether English and French practice differed.

Mr. A. J. Grant wrote that with regard to steel-making in the Sheffield district it is common knowledge that the monks of Kimberworth actually produced steel of a sort as early as the 12th century. It is known that the art of hardening steel was known in Sheffield in Chaucer's time by his reference to the Sheffield "thwytel" in his Canterbury Tales, and whilst it is commonly understood that the steel was largely imported from Sweden, yet we have reason to think that the cementation process with which Mr. Rhys Jenkins so largely deals was understood in this district at a very early age and for the following reason: The said monks of Kimberworth and elsewhere used to produce files by cutting the teeth in wrought iron and then carburising them by heating to a high temperature in contact with burned leather and charcoal. After this carburising, having quenched the file out in water or various solutions, they obtained reasonably satisfactory files.

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In Dr. Gatty's edition of Hunter's "Hallamshire" reference is made to what are known as Bole Hills, viz.: "The mode of smelting was very simple; on a bole or place selected on the summit of a high hill which was exposed to the prevailing west wind they placed a hearth of sandstone and then with a piece of wood or charcoal they extracted a small quantity of molten metal, no doubt a very insignificant portion of what the ore could have been forced to yield, but the quality was very fine; for it is well known that the best portion of the iron ore melts at the lowest heat and therefore the hot blast of modern use whilst increasing the quantity deteriorates the quality of the metal. But the product of these air bloomeries was very valuable of its kind as it was in its first fusion of the nature of steel; so that what is now obtained by a various and expensive process was gained straightway by the primitive method."

Colonel N. F. Belaiew supplemented his remarks at the meeting by the following communication: The Swedish metallurgist, Bergman (1735-1784) seems to be responsible for the first analysis of carbon in iron. According to Bergman, the content of carbon in steel is between 0.3 and 0.8 per cent., and between 1 per cent. and 3.3 per cent. in cast iron. However, it would only be fair to state that besides the influence of carbon, Bergman attributed, like all his contemporaries, a great importance to "Phlogistique." Still, his views, and especially his analyses were much ahead of his time. For the determination of carbon he used the same method as we are using now, namely, to oxidise carbon into carbon dioxide.

Guyton de Morveau, in 1786, gives a critical survey of the views of Réaumur and of Bergman, and comes to the conclusion that the conversion of iron into steel is definitely due to its combination with carbon. To demonstrate that, he uses the action of acids, and shows that carbon remains either as a non-soluble residue or as a blackish powder. From the details he gives it is quite clear that the first is graphite and the second is cementite. It will be interesting to mention that simultaneously with Guyton de Morveau, Dr. Priestley was making his experiments at Birmingham, using the same method of dissolving steel specimens—in his case Birmingham nails—in sulphuric acid. He gives the weight of cementite remaining after the action of the acids as 68.75 parts for 1,000 parts of nails, or 6.88 per cent. of cementite, which gives 0.46 per cent. of carbon.

It seems to follow that Priestley and Guyton de Morveau simultaneously came to the same conclusion about 1786, and I am inclined to think that that year might be taken provisionally as the year definitely marking our knowledge of the composition of steel. For further details he referred to an article of his, "Les Précurseurs de la Métallographie," in the *Revue de Métallurgie*, 1912.

Mr. Jenkins wrote: In reply to Professor Desch I may state that the furnace

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shown by Réaumur (L'art de convertir le fer forgé en acier, 1722) is one of his own design, and there is nothing to suggest that it was on a manufacturing scale. Réaumur mentions two furnaces of the glass-house type that had been put up in France by Englishmen, but the manufacture of steel by the cementation process did not take root in that country until long after his time. It is likely that the first cementation furnace put up in the Sheffield district had the domed roof and external cone. It will be noticed that the furnace at Kingswinford, Staffordshire (1686), described in the paper, is somewhat of this type.

As regards Mr. Grant's observations on the process used by the monks of Kimberworth, there can be no reasonable doubt that it was case-hardening as described by Theophilus in the eleventh century.[27] Files and rasps seem to have been made in this way as late, at any rate, as the early part of last century. The writer is of opinion that steel was made in Hallamshire in the first instance direct from the ore in bloomaries, then, after the introduction of the blast furnace. from cast-iron fineries, and then, about the year 1659, from wrought iron by the cementation process.

Colonel Belaiew's statements are interesting as amplifying his remarks as to the date when chemists first understood the rôle played by carbon in steel.

[27] See the foot note ante p. 20.

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APPENDIX.

Sir Henry Sidney's Steel Works.

Since the preceding paper was presented, the writer, by the courtesy of the late Lord de l'Isle and Dudley, has had an opportunity of inspecting the books of accounts relating to the Iron and Steel Works of Sir Henry Sidney in the Penshurst MSS. Of these books transcripts have been made of two which seemed to be of particular importance in relation to the introduction of steel-making, viz.:

No. 387. "The Booke of the Generall Accompte of the Stelle Workes, 1566," and No. 372, "A Declaracon of the Reconing of the Steele Workes, in Kent[1] belonging unto the right honorable Sr Henry Sidney of th'order of the Garter, Knight, Lorde President of Wales and Lorde Deputie of Irelande, Edmunde Roberts of Hawkhurste in the said Countie gent. and Jone Knight of London, widowe, the late wife and Administratrix of the goods and cattells of Raffe Knight, Owners and Copartners of the said Workes . . . . from the xth daie of December in the xth yere of the raigne [1567] of our soveraigne Lady Elizabeth by the grace of God of Ingland, Fraunce & Irelande, Quene, Defender of the faithe etc. Untill the xviijth daye of Aprill then next ensuing, viz. by the space of fower monithes and od. Daies."

These transcripts are far too long to print here, but the following is the story that emerges from them:

In the course of the year 1564 Sir Henry Sidney's agent in Flanders engaged two "Dutchmen" [i.e., Germans], John Frolycke and John Bowde or Budde, to come over to England "for the Tryalle of the Mynes for the stele." These men appear to have been superior to the ordinary master workmen, perhaps we may call them "experts," and it would seem that their engagement was merely to start the works. They were engaged under contracts by which each was to receive the sum of 2,000 dollars (for conversion into English money the dollar was reckoned as five shillings). At any rate, in March, 1565, they came over to England, and after spending about a month here, possibly examining the product of the blast furnaces and viewing sites for the works, they returned to the Continent to procure men and appliances. It would seem that they were not satisfied that the Sussex iron was suitable for steel-making, for upon Bowde's

[1] In so far as the Robertsbridge works is concerned the heading of this account is incorrect. Robertsbridge is in Sussex; but, as will be seen later, there was another works, and it seems likely that this was in Kent.

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second coming to England, towards the end of June, he and three other men, "myners and Bergeknighten," proceeded direct from London to Bristol for Wales. At the end of July, Bowde is back again from Wales "with the myne" and proceeds to Antwerp. In the course of September the accounts show charges for "postage of letters out of Duchlande to Andwarpe," money given to Bowde "to paie unto Gervaise the M^r of the works for anvells, formes & elles provided by them in Duchland," and "at his goinge out of the hye countrie with the Duchmen," other payments to Frolycke and Bowde, and payments for clothing for them and other Germans. On October 3rd Bowde goes to Utrecht for the forms and other necessaries provided in Germany and no doubt brought down by the Rhine. On the 4th there is a payment for bringing over certain "Duchmen" to Rye, and on the 9th Gervase and his company arrive, travelling by Canterbury. The company appears to have comprised seventeen persons. Bowde is still on the Continent, and on the 19th he proceeds to Cologne in search of more masters and men to take over to England. His efforts were not very successful, for he left Antwerp for England on December 24th with two or three men only. However, during the year 1566 there are many references to new men coming over, also to others who went back to their own country, including four who decamped.

It is not possible to say how many foreign workmen were in employ at the same time, probably the number was about thirty. Many of them are mentioned by name. John Frolycke and John Bowde have been mentioned above, also Gervase Krisker (or Brisker). Others were Harman Bowde, William Frolycke, Peter Kriskar, Adolp Zincke, John Ferderbecker (Federbeck), John Cromer, Jacob Scult, John Bearmane, Roquis Smorde (Rocus Smede), Semper van Loue, Harman Crine, Pete of Breckerfillde, Henericks, Corte, Powle, and John Quakenberge (brough). Some of these men were accompanied by their wives and families.

The number of forges set up is not stated, but it is clear that in addition to the works at Robertsbridge, there was another at Baxhurste or Bexhurst. Each works was under its own master, or manager, who produced the steel by contract.

The production of steel at Robertsbridge had fairly commenced early in December, 1565, and apparently at the start local iron was used. We find an entry of a payment to a carter "for bringing the plats from Chingley fornes," a note of the delivery of about 12 cwt. "for the stele works," it would seem from the Robertsbridge furnace, and a payment to "Thomas Butcher for 8 plats for the Stele Works." Then, soon after these, we have an entry: "Item p^d for fraighte of 21 tonnes of Plats from Cardife in Walles to Rie in December 1565

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33. 00. 0.," and from this time onwards, so far as the accounts show, all the cast-iron plates for making steel were brought from Wales.

For the production of these plates Sir Henry Sidney and Edmund Matthews rented a works in Glamorgan.[3] One of the books of accounts relates to that undertaking. Mention is made therein of the founders and fillers, of myne, marl, limestone, wood, coles, sows and washed iron (worked out of the cinders), and it is stated that three tons of sows made two tons of wrought iron. There was a forge in connection with the works. For the year 1567-8 we read:

" Plats for steel from last account	10 tons 750 lb.
Cast this year	67 tons 750 lb."

Each ton of plates cost £4 3s. 10½d. to produce. The carriage of 80 tons of plates from the furnace to Cardiff cost £13 6s. 8d., and the charge from Cardiff to Rye was then £1 a ton. The rent paid for the furnace and land for one quarter was £4 11s. 3d. Some of the workmen here were foreigners. "The Booke of the Generall Accompte of the Stelle Workes, 1566," has an undated entry: "p^d for the Duch founders charges . . . . in London at ther goinge into Walles"; another entry is: "p^d for 12 yard ¼ and ½ of new color for the Duchmen in Walles at 8^s the yarde."

The steel was sold in firkins at £6 and £7 a firkin. What the weight was is not stated, perhaps about six cwt., as it took 9½ cwt. of iron to make one firkin. Lower units of weight than the firkin were the burden, and the sheaf, six sheafs went to the burden.

In the four months, December, 1567—April, 1568, covered by the account in document No. 372, 57 firkins were made. The payment to the steel-makers was 31 shillings a firkin; it had been 30 shillings in 1566. Three loads of charcoal were consumed in making each firkin and the total consumption of iron was nearly 28 tons; in the same period 40 tons were received. At the stock-taking this iron was valued at £4 a ton and the steel in hand at £5 a firkin.

It has been stated above that the production of steel commenced early in December, 1565, and the evidence of this is one of the items in the accounts of steel "Sold in the house per the burden & sheafe from the 15 io^r of December 1565 unto the 26 io^r of September 1566, 129 borden, 3 sheafe for the some of £38. 17. 0." The wholesale trade in London began on March 20th, 1566, when five firkins were disposed of to four separate purchasers at £7 per firkin. The quality of the material must have been at least fairly satisfactory, for we find the same men repeating their purchases from time to time. The largest buyer was a man named

[3] One judges that it was in the Taff valley, within easy reach of Cardiff, perhaps at Pentyrch, where about thirty years later another Edmund Matthews was casting iron guns. Possibly the ore employed was the hematite found in that locality.

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Winch, who up to August 19th had taken 23 firkins in lots of two, two, seven, and twelve. Later on, at the end of 1567 and beginning of 1568, he still figures as a buyer, but for smaller lots; the price had now fallen to £6, in August, 1566, it had been £6 10s. The sales were not confined to London; firkins of steel were sent to York, Coventry and Ipswich, as well as to Wales and Ireland.

The iron plates from Wales were brought by sea to Rye. Similarly Rye was the shipping port for the steel. Communication between Rye and the works was effected by lighters along the river Rother. The wharf for the Robertsbridge works is referred to as the "ocke"; it was probably at the point known as Bodiham Oak, a short distance below Robertsbridge Abbey. For the Bexhurst works use was made of a wharf lower down the river, at Bodiam. The site of these works has not been determined, but the fact that a wharf to the east of that used for the Robertsbridge works suggests that it was in that direction. There is no trace of the name Baxhurste or Bexhurst in the neighbourhood, the nearest approach to it is Boxhurst. The six-inch ordnance map shows Great Boxhurst and Little Boxhurst above five miles north-east of Robertsbridge and south of Sandhurst. So far as is known no traces of works have been found at either of these places, but that need not surprise one, for the works cannot have remained in operation for any great length of time and the buildings put up seem not to have been of a very substantial character, the workhouse, two large coal-houses and two dwelling houses cost about £100.

As to the Robertsbridge works, it is pretty clearly established that they stood on the site of the Abbey, and that the conventual buildings were utilized, and possibly some of the ancient buildings still remaining may have been used by the steel-makers.

These accounts are full in some respects, but deficient in others. For instance, we find nothing about the construction or cost of the forges. It would seem that they were built by the German workmen from materials which are included in the accounts but not charged to any particular purpose. There is an entry: "P^{d}. Snayth for settinge up a fornesse and breking a dore in a stone wall and makinge a windowe 00. 06. 0.," but there is no indication of the purpose for which this furnace was intended. There is no mention whatsoever of a waterwheel, so it must be taken that the bellows were worked by men, also that the hammers were hand sledges. That the works did not depend upon water power is a factor to be borne in mind in any attempt to fix the site of the Bexhurst works.

In regard to the bellows, however, we are in a better position; there are quite a number of entries relating to their construction and to the provision of oil

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and tallow for dressing them. These entries have been collected and are given below:—

THE BELLOWS.

Item p^{d} frinde of Dresynge for 6 hydes for the belowes the 13th io^{r} of October 1565 ... ... 00. 12. 0

Item to the workes ½ C and 5 l^{i} of Yron to make hoppes for the bellowes 00. 05. 6

Item p^{d} the Sawiers for ij daies sawinge of bellow bordes the 25th daie with their borde 01. 01. 0

Item p^{d} John Dewcke for 16 hydes had of him for the belows at 6/8 the pese 04. 16. 0

Item p^{d} James Barden for 26 daies worke about the making the belowes at Robersbridge 01. 16. 0

Item p^{d} him more for drawinge the belowe pipes and for 2 l^{i} of candell 00. 06. 8

Item the 18th io^{r} p^{d} a coriare for to help dresse the belowes & for 2 shetes of lead, spent about them then 00. 02. 2

Item p^{d} Ric. Vousden for 17 io^{rs} worke about the makinge of the belowes 00. 10. 0

Item paide Edwarde Bennett for work done about the said Belowes 00. 04. 8

Item the 30th io^{r} of December 1565 for 2 daies worke about the Belowes 00. 00. 10

Item for cutting of . . . . for ye belowes 15^{d} & making a sawe pitte 6^{d} & for 2 loads of below tymber & for 2 great logs for ye forge 2^{s} 00. 03. 9

Item paid the sawiers for sawing of timber for the belowes & tables — — —

Item p^{d} Richarde Gilbarde for 8 daies hewing of timber findinge himself at 14^{d} the daie 00. 09. 4

Item paide Wyllyam Weller for 8 daies hewing belowe bordes finding himself at 12^{d} the daie 00. 08. 0

Item p^{d} Robert Orege and his p^{tenor} for 7 daies ½ saweing of belowe bordes beyond Flymwell at 14^{d} the io^{r} 00. 08. 9

Item p^{d} Mudells wyffe for the Sawiers borde that sawed the bellowe bordes 00. 09. 0

Item p^{d} Thomas Bericke for 20^{li} bellowe nailles for ye bellowes ... 00. 07. 6

Item p^{d} Edmund Wevor for 7 hides for the bellowes at 6^{s} 02. 02. 0

Item the 12th io^{r} p^{d} Robert Erige & his p^{t}nor for 3 io^{rs} sawinge bellow bords at 14^{d} the daie... ... ... 00. 03. 6

Item p^{d} for ther borde these 3 io^{rs}... ... ... 00. 03. 0

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Item p^{d} John Dewke for 6 hides for the belowes at 6^{s} pece	01. 16. 0
Item the 21 io^{r} dito p^{d} Edmund Wevor for on hide for the belowes...	00. 06. 0
Item p^{d} Vowsdey of Goudhurst for worke done by him about the belowes	00. 08. 0
Item p^{d} for his borde the same time	00. 03. 6
Item p^{d} James Barden for drawing of 12 paier of belowe pipes for Baxhurste	00. 12. 0
mor for 8 paier of belowe pipes	00. 08. 0
Item p^{d} Frinde for dressing of 16 hidds for Baxhurst	00. 08. 0
Item p^{d} for a C 2^{d} nailles & shepeskyn for the belows	00. 00. 7
Item p^{d} to fylpote for a shepeskyne	00. 00. 5
Item p^{d} James Barden in p^{t} of payment of making of belowes & suchelyke	00. 10. 0
Item p^{d} for a gallon of flower for the belows	00. 00. 4
Item p^{d} for 5 plattes for the belows	00. 01. 3
Item p^{d} on for trimynge of the belowes	00. 00. 4

OIL AND TALLOW FOR THE BELLOWS.

Item p^{d} for 2 gallons and a quarte of tranie	00. 05. 2
mor 23^{li} of tallowe at 3^{d} the l^{i}	00. 05. 10
Item p^{d} for bindinge a hogshed of trayne uylle & setting 8 hoppes in yt	00. 00. 8
Item the 7th io^{r} of Maie 1566 to the works 6 gallons of trayne at 18^{d} the gallon	00. 09. 0
Item p^{d} for 4 gallons of trayne for the belowes at 18^{d} the gallon ...	00. 06. 0
Item mor for 18^{li} of tallowe hade of Gervase	00. 08. 9
Item p^{d} for 15^{li} of tallowe for the belowes at 2½^{d} the l^{i}	00. 03. 1½
Item p^{d} for 2 gallons of traine at 18^{d} le galon	00. 03. 0
Item the 24 of September 1566 p^{d} for 2 gallons traine	00. 03. 0
Item p^{d} mor for 6^{li} of tallow at 2½^{d} le l^{i}	00. 01. 3

Of the miscellaneous building materials that appear in the accounts, nails take a prominent place; we have twopenny, threepenny, fourpenny, fivepenny, and tenpenny nails in a large number of entries, to say nothing of bellows nails, and "prigges" or sprigs. Various purchases of "bordes" are made, and half a thousand bricks are got from a man at Ewhurst for 3s. 4d.

In the matter of tools, "1 chesell, 3 axses, an on agore for the Dutchmen" are bought for 8s. 7d.; a "matoke" and a spade for one shilling each, and a shovel for 10d. Two grindstones are got for the Robertsbridge works at a cost of 8s., and later two others for Bexhurst at 6s. There are payments for "making hamers and anvelles for the Dutchmen," "for steele for the Duchemen to make the tools with," and for lamb and sheep skins, presumably for aprons.

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The entries relating to the purchase and cartage of wood and charcoal are very numerous, and it seems that pit coal was being used at the works for some purpose, for we find one man paid "for fechinge of 5 carts of se colles from the place" and another "for bearinge of 16 loads se colles into the house," i.e., the workhouse.

Turning now to more personal matters, we find many entries of payments made to and on account of the men in Flanders on their way to England for board, lodging, transport, and clothing. Some of them seem to have been fully fitted out with garments. Wawater Varhawgat at Antwerp was paid "for clothe had for ther (Frolycke and Bowde's) apparell 09. 18. 8d." A later entry is "P^d^ the tayller for makinge aparrell for Gervas, Budde & Frolycke wth other for lynynge to the same aparrell 07. 04. 10." After their arrival in this country there are payments for their transport, the charges of guides, etc., and for their board until the making of steel was actually begun. Sixpence a day per man seems to have been the charge for board at Robertsbridge. In October, 1565, 1s. 10d. is paid for "4 quarts of wine for the Duchmen," and in the following year a payment of 2s. 8d. is made to "Wiblis wife for a barrell of bere for the Duchmen." When he had settled into his own quarters two hogs are given to Gervase Kriskar; they cost five shillings. Some of the most interesting items relate to the purchase of bedding, as: "P^d^ for 22 elles a ¼ & ½ of canvas to make 3 beeds & bolsters thereto & for 20 stone of flox at 18d. the stone, and for making them 02. 07. 6"; "P^d^ for canvas & flox to make a beede for the Duchmen 00. 10. 0," "mor for thryde and makinge the bede 00. 01. 0"; "to the Duchmen 12 elles of canvas to make sheets at 9½d. thelle"; "to make a bolster 2 nailles of flox at 16d. the naylle"; "for a yarde of canvas and 4^li^ of fethers for to make a pillowe for them 00. 02. 8." In 1568 it was estimated that the value of the bedding bought amounted to £20.

Free medical attendance was provided for the men; it will be seen from the following items in the account that blood-letting was one of the remedies in vogue:—

Item p^d^ a surgane in pt of payment of curing ye Duchmen 00. 10. 0
Item p^d^ Mr Burrockes man for letting ye Duchmen bloud 00. 06. 0
Item p^d^ Mr Burrocke for lettinge the Duchmen bloude and for medcins for them 00. 04. 0
Item p^d^ Mr John the surgane for mynystringe of medecines for the Duchmen in p^t^ of payment... ... ... 00. 10 0
Item p^d^ Mr John the Surgant in full payment of all surgerie done by him to the Duchmen 01. 00. 0

Intercourse between the foreigners and the English was naturally difficult, and we find that when Frolycke and Bowde first came over a payment of 30s.

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is made to " a duchman that came from London to be an intorpretor between my Mr and them and was here the space of x daies." Later on, in 1566, 1*l* is paid to " John the Yntarpreter upon his wages."

A valuation of the property made in 1568 includes eight horses and a bull. As illustrating the value of money, it may be noted that the horses were estimated to be worth 16 shillings each and the bull 20 shillings. That is to say, that the eight horses were worth about the same as a firkin, say 6 cwt. of steel. The wage paid to the native labourers was usually six pence a day, but there are entries as low as five pence and as high as sevenpence. The accounts considered in the foregoing deal with the works up to the early part of 1568, and it is not possible to say from them how long the German workmen remained in England, or up to what date the works continued in operation.

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Notes on Old Windmills.

By Arthur Titley.

(Read at Queen's College, Birmingham, January 26th, 1923.)

The origin of windmills is obscure. Unlike water mills, they appear to have been unknown to the ancient Greeks and Romans. Although it is probable that they were introduced into Europe from the East, the oft-repeated statement that they were brought by, or followed, the Crusaders, is uncorroborated.

Sir Percy Sykes, in "Ten Thousand Miles in Persia," describes what would appear to be a very ancient form of horizontal windmill in use near the Afghan frontier. This has a vertical shaft with vanes at one end, driving the runner-stone at the other, thus having only one moving part, and is analogous to the Greek or Norse water-mill, which takes the same form, and is the earliest power-driven mill known.

An analysis of the mills mentioned in Domesday shows that the flat counties of Lincoln and Norfolk contained the greatest number. Although Domesday does not state the power by which these mills, (some 6,000 in number), were driven, the fact that in a little more than a hundred years after the Domesday Survey was made, windmills are mentioned in various records as existing in Lincoln, Norfolk, Suffolk, Essex, Sussex, Kent, Surrey, Lancashire, and Cheshire, points to the possibility that they may have been introduced into England at an earlier date than is usually supposed.

The first definitely accepted reference to a windmill in England appears to be that contained in the Chronicle of Jocelyn de Brakelond (1437), which describes the building of one by Dean Herbert in his glebe land at Bury St. Edmunds in 1191, and, by order of Bishop Sampson, pulled down.

The first illustration of a windmill in this country that we can approximately date occurs on a brass, probably Flemish, at King's Lynn, upon the tomb of Adam de Walsokne, merchant and Mayor of Lynn, who died in 1349. This shows a post mill of a similar type to that which can be seen working to-day. The post which carries the mill is fixed at the junction of two horizontal timbers crossing each other at right angles upon the ground. Inclined struts are framed to these timbers and to the post, the whole forming a rigid structure. Wide steps at the back of the mill gives the means of entrance to it, and a horizontal beam centred

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on the post and passing through the steps enables the miller to turn the mill bodily round to face the wind. (*See* Plate VI.)

In 1588 Ramelli published his work "Le Diverse et Artificiose Machine." Here we get our first view of the internal economy of a windmill, for Ramelli brings us at once into the realm of practical mechanics, and we are enabled to see a complete mill in much the same state of development as that in which was the post mill—Plate VI.—with its post frame placed upon four blocks of masonry upon the ground. The tailbeam is provided with a windlass, a rope from which can be fastened to any one of a row of posts driven into the ground in a circle round the mill, while a frame and wedges raised the steps from the ground while the structure is being turned to the wind. He also shows a tower or smock mill—Plate VII.—which became possible by the invention of the rotating cap, which, according to the Flemish writer, Leeghwater (1575-1650), was due to a Fleming in the sixteenth century. The engraving shows the cap carried on vertical rollers centred in the moving curb upon which the cap is constructed. Horizontal rollers guide it in a circular path. This method is the one most used in England to-day. Ramelli gives a third picture—showing a tower mill driving two chain pumps. On the wind shaft are fixed two lantern pinions which engage the chains. The whole pump construction is hung from the rotating cap and its lower end dips into a well in the base of the tower, from which the water is lifted to a circular tank at the top of the tower. (*See* Plate VII.)

All the framing and gearing of these mills are of wood, the only important parts of iron being the wrought iron gudgeons upon which the shafts revolve, and perhaps the "quants" or spindles which drove the runner stones. A simple wheel and axle hoist, operated by hand, assisted the miller to raise the sacks of corn to the floor upon which the stones were situated. An exceedingly interesting feature is here exhibited in the brake embracing the wheel upon the wind shaft, by which the mill was stopped when required. A band surrounding this wheel is attached at its free end to a lever. This lever is weighted so that normally the brake is on. A rope passing over a sheave in the cap enables the end of the lever to be raised by means of a winch when it is necessary to release the brake. Here we see the underlying principle of all modern safety devices understood and applied by the millwrights of Tudor days.

D'Acres' "Art of Water Drawing," published in 1660, contains an interesting reference to windmills, which is worth quoting as showing considerable appreciation on the part of the author of the principles involved. He says:—

> "*Instruments* peculiar to the *wind in making motions*, are only *sayles* as yet in use; and these are of three *sorts*, differing chiefly in their *posture* and the manner of placing them. The first sort are *hanging downright*, the other,

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set *level*, the 3 sort *screw wayes*. The first sort (being *perpendicular*), are the most usual and best, being commonly used in corn mills. The other sort call'd horizontal sayles are of little use and lesse worth, they will move, but not equalling the strength of one *horse*. Some of these are made to go with *shrouds* or *shelters*, others without: those without *shrouds* give a *broad side* to the driving *wind*, and come more closely up against the wind, the sailes falling off at the utmost Ends, or closing together: either of these wayes hanging upon *Iron Gimbals*, are subject to sudden breaking in great winds; and also in danger the *Gins* set to them by their sudden *Girts* that every sail gives when it takes the wind with the *broad side*; and are therefore not in use in moving water *Gins*.

"The other sort of *Horizontal Sailes* with *shrouds*, move more quietly, but with no worthy strength, though the one half be shrouded never so well, as experience hath taught. The reasons may be these; the commanding sailes in the wind are but two at the most, and but one of them sometimes in full Strength. Then on the other side, though the *shrouds* may keep blasting *winds* away, yet neither it, nor anything else, can keep the *Air* away, and the sailes coming up against it with broad sides, receive thereby such a shock, as cannot be recovered by the other Side.

"The third sort of *sailes* are placed *screwwayes* upon an axis lying *horizontally*, as if *sailes* were fixed upon such an axis as a *shaft* of a wheel, (a little winding about the axis like a screw, but not much), the whole length of the axis, so that which way soever the wind cometh, except upon the two *poynts* or ends of the *axis*, the *sailes* are ready to receive it; all the nether part of it from the *Center* of the *Axis* downwards, is shrouded, as the horizontal sailes. These, (as some conceive), perform better service than the *horizontal sailes*, but not so much as the *perpendicular*."

Our next information, and by far the most important, is contained in the works on millwrighting published in Amsterdam in the early part of the eighteenth century. Of these, three[1] contain scale drawings of complete mills, from the inevitable piled foundation needed almost everywhere in Holland, to the auxiliary machinery which had by this date been considerably developed. In examining these books our attention is called to a conservatism in design and an elaboration of detail which clearly indicates that the art of windmill building in Holland had by this time passed through a long period of evolution, and had arrived at definite and accepted practice. We find full details of

[1] Pieter Linperch—Architectura Mechanica of Moole-boek, 1724.
Leendert Van Natrus, Jacob Polly, Cornelis Van Vuuren—Groot Volkomen Moolenboek, 1734. 2 vols.
Johannis Van Zyl—Theatrum Machinarum Universale of Groot Algemeen Moolenboek, 1734.

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the way in which the framed wooden towers were built and erected, and of the sails, shafts, and gearing. We see grinding mills for various grains, fulling and paper mills, mills for grinding snuff and cutting tobacco, for beating hemp, sawmills and mills for grinding and boring gun barrels, besides mills for driving scoop wheels and archimedean screws for pumping water. We can study here their methods of mortising and tenoning the framework together, of setting out the teeth of wheels, and of building up wheels, shafts and other mill-work parts; while even the tools they used and the capstans, tackles and lifting jacks they employed in the erection are illustrated.

Timber still remained the principal material from which they made their machinery. The drawings clearly show how their massive shafts and wheels were constructed. A particularly interesting picture shows that in making such a piece as the wind shaft the first process, after squaring the log sufficiently to obtain true surfaces to work from, was to carve out at each end a cylindrical projection or spigot upon which to rest the shaft and rotate it on temporary bearings so that it could be further wrought to a true form. The permanent journals were thus reduced to a circular shape, and in order to provide a wearing surface iron bars were let longitudinally into the journal and held in position by wrought iron rings placed on the ends of the bars. One illustration shows two millwrights at work fitting these bars into the recesses prepared to receive them. The spigots formed upon the ends of the shaft were usually left upon it so that the shaft could be truly rotated when any repairs to it were needed. This method of giving a metallic bearing surface to a timber shaft is probably very ancient, although I have found no earlier reference to it. It remained in use till the adoption early in the eighteenth century of cast iron gudgeons with what is called a "crosstail," by which they were attached to the timber body of the shaft, and it survived late enough to be carried to the United States, where it is recorded as existing in a windmill on Cape Cod. Cast iron appears to have been commonly used for smaller parts of mill work by the beginning of the eighteenth century, and many parts of this material are shown in the Dutch drawings. For instance, the ratchet wheels used for feeding the log through the gang saws in the sawmills shown are evidently of cast iron, and the gun barrel mill illustrated has two of the smaller shafts also of cast iron.

The bearings upon which shafts turned were probably of hard wood. Such bearings were in use for water-wheel shafts as late as 1784. Stone also was frequently used, and Van Zyl illustrates one such bearing in his book. Metal "brasses" were also used, and the same author shows a lower bearing fitted in a timber "headstock," which he describes as "Hals metaal" (neck brass). A derelict post windmill at Warton, in the Fylde district of Lancashire, had stone

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bearings of what, according to a local writer, was known as "blue boother stone," and the late Mr. Sidney Russell has recorded that South of England millwrights used "Nottinghamshire block" for the same purpose.

The auxiliary machinery shown in these drawings of Dutch mills would form a useful subject for study to anyone investigating the history of the various industries dealt with.

The fine corn-mill illustrated by Pieter Linperch erected near Amsterdam in 1685 (*see* Plate VIII.), has a sack-hoist driven by gearing from the vertical shaft, the earliest example of this that I have met with. The snuff-mill shown by Van Natrus has sieves driven by the mill with a vibratory motion. The "rag engine" shown in the paper-mill for tearing the material to pulp is in principle identical with those used to-day. The dropstamp principle, easily adapted within the restricted interior of the wind-mill tower, was frequently used by the Dutchmen. Examples are to be seen in the fulling-mill and the oil-mill, while the mechanical stirrer used in the latter, and the winnowing fan and the gun-barrel boring lathe are further examples of the variety of machines forming the equipment of the Dutch wind-mill at the end of the seventeenth and beginning of the eighteenth centuries.

From what we see up to Ramelli's day, the sails of a windmill were placed at a constant angle of "weather" to the sweeps which carried them. When we come to the Dutch works we find the idea of fixing the sail bars at a decreasing angle to the plane of rotation from the centre of motion in proportion to their circumferential velocity was fully understood, and they show us the method of setting out the proper angles of the mortices through which the sail bars passed. The method of trimming the head of the mill to the wind was usually that shown in the fourteenth century pictures in Green's "History." A winch attached to the tail beam was used in the same way, though Pieter Linperch gives us a case in which a Y-wheel, as it is still called—from the shape of the irons attached to its rim—and rope were used to give motion to a trundle gearing with an internal circular rack upon the cap, so that the head could be rotated from within the mill. A similar arrangement is to be seen in the Chesterton mill visited by Members of the Society at the Birmingham summer meeting, 1921, but in this case a winch in the head gears into a fixed rack inside the tower.

An excellent detail developed by the Dutchmen, which appears to have been generally used by them, was the mounting of the pins upon which the anti-friction rollers carrying the cap turned upon a "roll ring," as it was called, so that the weight of the cap was transmitted through the rollers direct without being borne by the pins. Smeaton, who visited Holland for the purpose of studying their mill practice, introduced this feature into English mills, although it does not appear to have been adopted here to any extent.

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Windmill construction in Holland appears to have reached its perfection at about this period. The automatic arrangements for controlling the sails and for keeping the head to the wind, invented and applied in England at a later date, never appear to have been adopted there, as any modern view of a Dutch landscape shows, but the elaboration of detail and excellence of construction has probably never been reached outside Holland. Indeed, an examination of their published work impresses the reader with the great debt that industry owes to the practical and industrious Dutch millwright.

About the year 1750 the Scotch millwright, Andrew Meikle, to whom we owe the thrashing machine, invented the "fantail" gear for automatically keeping the head of the mill to the wind. In this gear a small windmill placed at the back of the cap at right-angles to the main whips is geared with a reduction of about 3,000 to 1 to a circular rack fixed outside the top of the tower. This arrangement has been very largely used in England, the chief later development of it being the use of iron spur and bevel gear, whereas Meikle originally used worm gear. Wood worm gear has been frequently used and, I believe, examples are still in use.

Smeaton devoted much attention to windmills, and about the year 1755 introduced cast iron wind shafts and cast iron spur and bevel toothed rings in place of the usual wood mortice wheels, and in 1759 carried out his well-known experiments, in which he investigated the relation between wind velocity, horse-power, sail area, and angle of weathering, and in which it is noteworthy that he substantially confirmed the results at which the Dutch millwrights had arrived by practical experience.

Andrew Meikle, about 1772, invented an arrangement for automatically relieving the sails of windmills from excessive wind pressure. This he did by dividing the sail area into unequally pivoted divisions placed at right-angles to the length of the whip, coupled together by a rod to a spring fixed on the sweep near the centre. The tension on the spring could be regulated by means of nuts on the outer ends of the bars when the mill was stopped, each sweep being adjusted separately. A modification of Meikle's arrangement is in common use in English mills to-day.

No account of the machinery of a windmill would be complete without reference to the "lift tenter," which in Watt's time re-appeared as the engine governor. The origin of this has not yet been cleared up, but it was devised to automatically raise and lower the runner stone in corn windmills as the force of the wind and the speed of the mill varied, taking the place of the balance arrangement clearly shown in Rees's picture of the internal economy of a post mill, by which the height of the stone was adjusted by hand.

The "tenter" seems to have been unknown to the writers of the Dutch books, and I am not aware that Smeaton ever referred to it. It was therefore

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probably introduced towards the latter end of the eighteenth century. Although it was patented by Thomas Mead (No. 1628 of 1787) and by Stephen Hooper (No. 1706 of 1789), it was probably in use before that date. In the form illustrated by Mead the suspension joints of the pendulums are at right-angles to those of the steam engine governor—that is, the weights rose under the combined influence of "lag" and centrifugal force. Buchanan (1814) shows this form of "lift tenter," and I have met with four existing examples of it. One was working in a large eight-armed mill at Heckington, in Lincolnshire, which has the date 1830 upon the tower. The "tenter" referred to, however, was evidently acquired with a pair of stones, which it governed, from an older mill. In this mill there are four other pairs of stones all governed by a "tenter" of the governor type, the steelyard levers of three pairs being coupled to the fourth, which engaged with the rising collar of the tenter. Quite commonly several pairs of stones are to be seen thus controlled. The "lift tenters" are often attached directly to the quant or mill spindle, but are sometimes driven by belts from the vertical shaft of the mill, with an intermediate spindle to enable the speed to be increased.

Attempts were made at the latter end of the eighteenth century and the beginning of the nineteenth to govern windmills by automatically increasing or decreasing the area of canvas sails, but these attempts do not appear to have been successful. Stephen Hooper, in the patent cited above, describes such an invention. John Bywater (No. 2782 of 1804) patented a roller reefing gear in which a hit-and-miss arrangement allowed the sweeps to be reefed or unreefed from inside the mill. These devices do not seem to have had any success, although I have met with one mill in Lincolnshire using roller reefing gear with hand control upon each whip separately.

In 1807 (No. 3041), William, afterwards Sir William Cubitt, patented an improvement upon Meikle's reefing gear with opening louvres, in which he brought the controlling rod through the centre of the wind shaft to the back of the cap, where a weighted lever is raised automatically as the louvres open under the pressure of the wind. This gear and Meikle's fantail for keeping the mills to the wind have been very extensively used in this country and can still be frequently seen.

The horizontal mill never found favour with the Western miller. The reasons, no doubt, were those so clearly set forth by the author of "The Art of Water Drawing," quoted above. The idea, however, has always been a favourite one with the inventor, especially of the amateur kind; we find allusions to it as far back as the sixteenth century, and the work, by W. H. Ryff, published in Nuremberg in 1547, shows a small illustration of one as an inset to a plan of a town. Two illustrations are also to be seen in the William Reynolds's scrap book,

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one of which, by the Chev. de Betancourt, is taken from Prony's "Architecture Hydraulique."[2] The Journals of James Watt (Watt papers at Doldowlod) contain the following:—"April 11, 1779. Sunday at Lichfield with Mr. Wedgewood—to see Dr. Darwin's horizontal windmill," so the ingenious doctor was evidently attracted by the problem. The most ambitious attempt, however, was that of Stephen Hooper, who erected a corn mill on this principle at Margate. This mill is shown in Rees's Cyclopædia. It was still working in 1820. The vanes of the mill were screened by a circle of boards after the manner of turbine blades. Another of Hooper's mills was built at Battersea for grinding linseed, but was described in "The Ambulator" in 1811 as having been by that time converted to a malt mill.

The Author acknowledged his indebtedness in the preparation of this paper to Mr. H. D. Haines, Member, for much assistance; to Mr. Rhys Jenkins, Member, for allowing him to make use of the whole of his notes on the subject; and to Messrs. Judges, Limited, for permission to make slides from some of their excellent postcards.

The paper was illustrated by forty-nine lantern slides, a selection of which is reproduced as illustrations.[3]

On the motion of the President, a vote of thanks to the Author was passed by acclamation, and the paper was thrown open to

Discussion.

Mr. E. Lancaster Burne said that for nearly the whole of his life he had been interested in windmills, and at the present time was engaged in applying a new type to electric lighting purposes in country districts.

So completely had the Author treated the historical side of the subject that all he could usefully add were some considerations of the millwright's art. He would like to mention in passing that he witnessed the building, in 1887, of the windmill at Patcham (Sussex), which the Author had illustrated. It was said at the time that it would be the last windmill to be built, but as a matter of fact since then a derelict tower at Selsey and an old windmill at Barnham (Sussex) had been so extensively restored that to all intents and purposes they were new mills.

With reference to the "lift tenter" or regulator attributed to "Captain" Hooper, once a miller at Margate, it might be of interest to record that in an old deed relating to the sale of a windmill at Braintree and dated 1810, this appliance is mentioned.

[2] See Trans II., 134 (15).

[3] The blocks for plates V. and VI. have been kindly lent by the Editor of "The Engineer."

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As regards the constructive aspect of the subject, it might be said that a windmill owes its beauty to a perfect adaption of the means to an end. Actually the profile of a well-constructed sweep resembles an aerofoil in that the inclined leading edge corresponds with the "dipping front edge" rediscovered by Phillips in recent years and now applied to all aeroplane wings. He did not know when the inclined leading edge ("pull" in millwright's terms) was introduced, but it was certainly known to Smeaton who, in one of his reports, gives precise directions for its formation. It might be hazarded that the inclined leading board to the sweep arose from the practical necessity of turning the wind on to the sail portion, so as to avoid a fluttering of the edge of the cloth, but it added so much to the effect of the sail that it has survived in the comparatively modern shuttered sweep. The very word "pull" indicates an astonishing grasp of correct aerodynamic principles. In spite of this, however, one to this day occasionally meets with sails whose profile is a straight line.

Mill sweeps have taken various forms, but are generally either "narrow" or "wide" (the wide sweeps being sometimes called "double" or "barndoor"). The following portion of the sail, with respect to the "whip" or radial arm, and known as the "driving" side, has frequently no "weather" angle and in Dutch sail mills the tip bars are generally set at a negative angle so as to avoid an outward flapping of the cloth when the sweep passes the mill housing and compresses the arrested air in front of it. This negative angle when combined with an inclined leading edge makes very little difference to the driving power.

The pressure equilibrium point of the sail is not in the centre of its width, but towards the leading edge and the correct construction of the old millwrights is again exhibited. As might be supposed, the cloth sail gives a more powerful drive than the shuttered type, but it has no automatic regulating gear (although several devices have been tried in the past) and "on long dark nights with the sails clothed and going" a sail mill wants some handling in a gale.

The multi-sailed mill is no new thing and there are to this day examples of old eight, six and five-sweep mills, but in the first case four sweeps have generally been removed and less often two of the six sweeps. Millers generally say that six sails are "two too many," that "five are rather better than four"—except when repairs are necessary—and it is well-known that two sails will give more than half the power of four. For many years a mill in Surrey was worked with only two sweeps.

Wooden windshafts with the neck formed of bars and hoops of wrought iron are still to be found in England; there is, or was quite recently, an example at Benenden in Kent. The usual method of attaching the sweeps to the windshaft was by means of a massive timber cross, the members of which are variously called the "stocks,' "' backs," or "middlings."

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Like the author, he was impressed with the feat of drilling a cast-iron windshaft from end to end to admit the "striking" rod when it was desired to fit patent sail regulation instead of "spring" or "sail" sweeps. A mill at Outwood, Surrey, was so treated, a stationary drill being applied to the windshaft as it revolved during its daily work.

He had heard of, but had not seen, the Nottinghamshire block. An old millwright once told him that he had fitted a glass bearing many years ago to the six-sweep post windmill which until recently stood at Kingston, near Lewes.

In connection with post mills he might remark that although it was undoubtedly the earlier design, many still existed. Of the two mills at Outwood, one of which has already been referred to, the older is a post mill dated 1666. There is no great difference between this old mill and the post mill at Heathfield, built in 1855, which he rather believed to be the last, or one of the last post mills to be erected in this country. A usual dimension for the lower part of the post was 2 ft. square, but in the mill at Heathfield the post is 3 ft. square. An old oak-tree is invariably used for the purpose. A massive timber—the "crown" beam—is pivoted across the top of the post and this forms the starting point of the whole revolving structure.

Hollow post mills, although common in Holland, are seldom met with here; the well-known disused, but preserved, windmill on Wimbledon Common is an example of this sort of compromise between a post mill and a tower mill.

Personally he drew a distinction between a "smock" and a "tower" mill —deeming the first name to mean a timber tower of octagonal or (rarely) hexagonal form and the latter a brick tower. The immense tower mill formerly at Yarmouth has often been referred to; but it was not so well-known that a very similar one was erected at Beccles. This mill was in use when he visited it a few years ago.

Mr. Burne exhibited an album filled with illustrations of windmills.

In reply to a question by Mr. C. E. Greener as to the power developed by windmills, the speaker mentioned that the large post mill at Heathfield fitted with three pairs of stones for oat-grinding, had an auxiliary plant in the "round" house consisting of two pairs of stones driven by a 10 nominal h.p. undertype steam-engine working at 75 lb. pressure. The owner informed him that the steam plant was not equal to a good wind. He had seen the power curve of a large four-armed windmill in Denmark which was employed in generating electricity—the extension of this curve pointed to a development of 90-h.p. in a very strong wind—actually however the shutters were set to "spill the wind" at 35 h.p. It showed, however, what was possible if the mill could be permitted to increase its speed in the same ratio as the wind and if the endurance of the machinery could be disregarded.

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Mr. H. D. Haines said it might interest members to know that "bolting" the flour was not originally part of the function of the miller but was carried out by the "mealman," who might be and frequently was a baker. He could point to a sign in an Oxfordshire village where the baker described himself also as a "mealman." He could confirm the observation that post mills were rapidly disappearing.

Mr. E. W. Hulme enquired if there were any evidence in support of the conjecture that the windmill was introduced from the East through the Moors into Spain thence through France into Holland. If so an examination of records in France, Spain and even Morocco might prove a fruitful line of investigation.

Mr. E. B. Martin exhibited drawings of millwork.

The Author, in reply, said he was glad to hear Mr. Lancaster Burne's remarks as they are the result of many years observation. The angled leading edge and the graduated angle of "weathering" of the sail-bars as well as the placing of the greater proportion of the length of the bars on the after-side of the whip, can be confidently attributed to the Dutch millwrights. The illustrations of Ramelli and the "Nova Reperta" show the bars equally disposed, and there is no indication that they were given a graduated "weather."

A fine post mill of date 1730 near Wrangle, Lincolnshire, which was visited in 1921, was observed during a high wind to rotate when the sails were furled, and the feed was off the stones, the area of the inclined surface of the bars being sufficient to produce motion. This indicates that the old mills were not necessarily inefficient mechanically.

The Author said he was unable to adduce any evidence in support of Mr. Hulme's very illuminating suggestion.

Correspondence.

Mr. Rhys Jenkins wrote that the Author had covered the ground very completely and had put together a very interesting paper. He was quite right to omit the statement that windmills were in use in Wales in the fourth century; it is almost certain that this was not the case. The prominence given in the paper to the Dutch milling books was deserved, as they are undoubtedly valuable works. It had been suggested that the not uncommon local name, "Tenter Lane," had some connection with the lift tenter, but unless definite evidence could be adduced coupling the name with a windmill, the writer inclined to the opinion that it would be found to be derived from a tentering ground for cloth.

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Indian Cotton Prints and Paintings of the 17th and 18th Centuries.

By G. P. Baker.

(*Delivered at the Hall of the Alpine Club, Feb. 7th,* 1923.)

Mr. Baker did not submit a formal paper, but conducted the Members round the Hall, on the walls of which the more important pieces from his unique collection—the result of thirty years' study of the subject—had been hung in order that they could readily be inspected. Upon these exhibits, together with a copy of his printed work,[1] he based his remarks; the following was the substance of these remarks:—

The process of cotton painting or printing, it is agreed, originated in India, but how long ago he was unable to say. A printed fabric found as a shroud of a Scythian warrior, dating from the fourth century B.C., gave an indication of its antiquity. The process was known to Pliny the Elder in the first century A.D., for he describes it in his *Natural History*, Book XXXV., thus:—

> "Garments are painted in Egypt in a wonderful manner, the white cloth being first stained in various places, not with dye-stuffs but with drugs, which have the property of absorbing colours. These applications do not appear in the cloth; but when the cloths are afterwards plunged in a cauldron containing the dye liquor they are withdrawn fully dyed. It is wonderful that, although there be only one dye in the cauldron *the cloth is dyed in several colours, according to the different properties of the drugs which have been applied to different parts;* nor can the colours be afterwards removed. A cauldron, which would of itself only confuse the colours on cloth previously dyed, in this way imparts several colours from a single dye-stuff painting or dying as it boils."

Whether Pliny got his knowledge from India or not, we do not know. The trades in painted and printed fabrics are known to have been extensive in the ancient world, distribution from India to Europe having been effected along the trade routes viâ Bagdad, Damascus and Egypt.

So far as he knew, no examples of ancient cotton printing are to be found to-day in India, though there are indications that in the treasure-houses of the

[1] Baker, G. P. Calico Painting and Printing in the East Indies in the XVII. and XVIIIth Centuries, folio, with Atlas of Coloured Plates, 1921.

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Rajahs—such as that of the Nizam of the Deccan—wonderful examples will yet come to light. The fact is that, as far as India is concerned, the industry as a living force has passed away. The speaker had visited India in 1920, but found nothing more recent than the manufactures of thirty years ago, and these were decadent. This decadence had set in even in the times of the Hon. East India Company—a fact remarked upon by the officials of the day—when the industry was still an important one.

From an examination of the records of the East India Company at the India Office, the speaker gathered that Madras was originally garrisoned for the protection of the industry, the workers in which were a community within the state. The Indian productions had a secondary interest, too, in that the fabrics used were made of Indian cotton, spun and woven by hand.

As far as Western Europe was concerned, it was safe to say that the process of printing in indelible colours was unknown before the 17th century. It was true that a form of printing analogous to that of printing on paper by means of blocks with colour ground in oil, was used earlier, especially for ecclesiastical purposes, indeed the manufacture was carried on by the monks. (Examples of this work may be seen at the Victoria and Albert Museum.) The migration of the industry may be traced from east to west by way of Asia Minor through the Armenians, who were from early Christian times the great commercial link between Europe on the one side and Asia on the other; throughout Asia Minor, Constantinople, Thrace, Greece, to Avignon in France, the speaker had found relics of their work and print shops or factories. [Here an altar frontal of Armenian *provenance* of the 16th century was pointed out.]

The early calico print works in this country were centred in the neighbourhood of London, and were inseparably connected with the bleaching industry which at the end of the 16th century was established in the valleys of the Wandle and the Cray. We may conclude that the masters were men of small means, perhaps bleachers (" whitsters ") of linens, and of the Indian cotton piece goods which, being sold by auction at the Royal Exchange, were sent to the bleachers, who, in course of time, having acquired the Indian method of printing, were induced to take up the print industry in conjunction with their bleaching fields.

Towards the end of the 17th century the industry may be traced firmly established in this country, print works being recorded in 1690 in the Old Deer Park, Richmond, and followed soon afterwards at Waltham Abbey, Merton Abbey, Mitcham, Wandsworth, Crayford, West Ham, and Old Ford. At Crayford, where his own works are situated, there is no direct evidence when the industry of printing was first established. It is known that linen weaving was carried on in the village in Queen Elizabeth's reign, and by an odd circumstance the Rector of Crayford in the year 1702 very wisely recorded the past occupations of the dead then

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being buried. By this means we are enabled to say that whitsters are recorded as being in evidence as a trade occupation. There is, therefore, every probability that printing very soon followed the work of the bleacher. The pattern books at his works go back to 1793, but from 1840 they are very complete, and enable one to trace the large field of work covered by the firm's predecessors over a period of one hundred years.

Dwelling for a moment on the artistic side of the productions, the speaker had no hesitation in saying that the Indian designs had never been surpassed—there was a fascination about them that grew upon one the longer they were studied. He ventured the opinion that the original artists were miniaturists. It was remarked with how few colours their results were obtained. These might be said to be four primary colours—red, blue, yellow and black.

Coming now to the technique of the process, it might be said that, broadly speaking, whatever we know about calico printing we owe to India. Nowadays the process has been speeded up and cheapened by mechanical aids—first the wooden block and then the engraved copper roller—also the underlying chemical reactions were understood and quickened, but practically little or no new principle was employed.

We owe our knowledge of the process as carried out in India to the writings of the Jesuit Father, Cœurdoux,[2] and probably it had not changed appreciably from early times.

The speaker here quoted from his translation of these communications, observing that the letters exhibited remarkable patience, and that Father Cœurdoux seemed to have followed every process communicated to him by the natives with infinite care.

The following is a summary of the Jesuit Father's communications:—

(1) The unbleached cloth is first treated in a series of preparations in which buffalo milk and myrobalams form the principal ingredients. This infusion with the fatty matter derived from the buffalo milk goes towards forming the mordant for subsequently dyeing with the "chay" or madder root to form the reds, pinks and clarets. The infusion furthermore fills up the pores of the cloth, and with the beetling it gets, from beating by a smooth piece of wood, imparts a fine surface to the cloth, and so permits it to be easily drawn upon by pencil or brush; it also prevents the colour when subsequently applied from spreading beyond the confines of the design.

(2) When these preliminary preparations are completed, the cloth is now ready for the design to be transferred to the cloth, by pouncing with charcoal dust, and then lined in with brush or pencil with a specially prepared iron liquor made by a crude method of reducing iron dross into a

[2] Lettres Edifiantes et Curieuses, 1748, XIV, 217.

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ferrous state to which must be added fermented rice water. We are assuming that black is the colour of the outlines which are to be first lined in, and in view of myrobalams forming part of the original ingredients in the preparation of the cloth, they act as a mordant and help to improve and develop the black. Having pencilled in the outline of the design with the iron liquor where needed (*see* Plate X., Fig. 1), the cloth goes through many of the original operations of steeping in buffalo milk, beetling and scouring, and if any portion of the ornamentation in the reds, pinks, or clarets contain any of the very fine white feather tracery or lace work so much in evidence in the best Indian work, this white effect is produced by a fine pencilling of wax to act as a resist to the dyeing operation which followed.

Alum is the mordant to produce the reds and pinks, and being an invisible colour when in solution, sapan wood is added to impart a pinkish colour that acts as a guide to the penciller when applying the mordant. The observation made by Pliny, and referred to by the author of these notes on page 52, now comes into operation in the production of the reds, pinks and clarets. The mordants for each of these will vary, but not so the dye bath—one dye bath may produce many shades, from a dark claret to a pink "*according to the different properties of the drugs which have been applied to different parts*"—a deep red requires a full strength of alum, whilst a pink a weak solution of alum, and the claret a mixture of alum and the iron liquor used to produce the black outline. The red dye bath of the chay root is heated to a degree such that the hand can no longer bear the heat (*see* Plate X., Fig. 3). The stained cloth of Fig. 3 is a superficial stain and easily removed in soap and water.

The next operation is to prepare the cloth for the blue colour, and for this numerous scourings in sheeps' dung are necessary in order to remove all traces of former operations, which would otherwise cause the blue to become black. Furthermore, as the cloth when originally treated was unbleached, the next operation is one which by exposure to the sun with constant sprinkling of water helps to bleach the cloth, and after further beetling and a dipping in a bath of fermented rice water, the cloth is made ready for the colour. Now the blue is not painted on with a brush, but applied by dipping into an indigo bath, but before this can be done the cloth must be gone over with wax everywhere, except in such places as are appropriated to blue or green (*see* Fig. 5).

This wax may be put on with an iron pencil as lightly as possible on one side only, taking care that the wax is not pencilled on any parts except where required. When this is done, the cloth is exposed to the sun; and careful attention given that the wax only melts just sufficiently to penetrate to the

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other side. The preparation being now complete, the painter hands over the cloth to the indigo dyer, whose business is a distinct trade which runs in families, and is handed down with its secrets from father to son. When the dyeing is completed, the wax is removed by immersing the fabric in boiling water and then skimming off the wax which will be found to float on the surface. Fig. 6 shows the cloth cleared of the wax.

If the green colour has to be painted on the cloth, like preparations have to be made all over again.

The last and final application is the yellow which serves for green by painting on blue, and yellow when painting on white (*see* Fig. 7), but this colour is not permanent.

A word must be said as to the Indian pencils. They consist of nothing more than a piece of bamboo wood sharpened and split at the end for a distance of a finger breadth. Fastened to it is a small portion of material, saturated with the colour it is desired to paint, which is squeezed out by the fingers. The pencil used for painting wax is of iron, split at the end, and forms a circle in the middle, around which are fixed tufts of hair about the size of a nutmeg; these hairs absorb the hot wax, which trickles from the end of the pencil when being squeezed.

The speaker remarked that it would be seen that the whole process was tedious in the extreme, for as many as twenty-six operations might be needed before the cloth was completed.

The plates referred to above[3], illustrating the Indian method of production, were copied from examples supplied to the speaker by Mr. Hadaway, of the Madras School of Art, and may now be seen at the Victoria and Albert Museum.

Discussion.

In reply to Mr. Pendred, the speaker said that the indigo dyer's trade was, and is to-day, separate and distinct and hereditary. The dyers engage in no other colour.

In reply to Mr. Brownlie, the speaker stated that in his works at Crayford the steaming process was used. He printed from blocks by hand, but he was putting in an unusually large machine to print from rollers in sixteen colours with a repeat of one yard.

A vote of thanks to Mr. Baker for his discourse and for the trouble and expense that he had incurred in bringing and displaying his collection was carried by acclamation.

[3] It is a matter for regret that, owing to the expense, it was impracticable to reproduce these in colours.

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The Early History of the Coal Gas Process.

By David Brownlie, B.Sc., F.I.C.

(Read at Prince Henry's Room, Fleet St., March 20th, 1923.)

The evolution of gas from decaying vegetable matter had doubtless been known for many centuries, and in 1600 Van Helmont, a famous Dutch chemist resident in Brussels, had observed that coal "did belch forth a wild spirit or breath." The word "gas," in fact, seems to have been originated by Van Helmont, being apparently derived either from the word "*geist,*" German, "*geest,*" Dutch, "*ghost,*" English, or perhaps from "*gast,*" meaning yeast. The earliest account of an illuminating gas given off by coal is that of Thomas Shirley in the "Philosophical Transactions" for 1667. He noticed gas issuing from a spring near Wigan, and on collecting samples, found that it would light, although he had no ideas with regard to its origin. The first man who seems to have observed the evolution of an illuminating gas by definitely carbonising various forms of vegetable matter, including coal, would appear to have been Robert Boyle in 1691. In 1726 Dr. Stephen Hales mentions early experiments on carbonising coal in his publication "Vegetable Staticks."

We now come to the Rev. J. Clayton, Dean of Kildare, who also experimented with the inflammable gas at Wigan, but who rightly surmised that it came from the coal seams below. He then heated coal in a vessel over an open fire, and in his own words: "at first there came over only a little phlegm, afterwards a little black oil and then likewise a spirit arose which I could in no ways condense." Clayton wrote to the Hon. M. Boyle describing his experiments, in which he speaks of gas as "the spirit of coals," and this letter was published in the "Philosophical Transactions" of 1739[1].

Coal was apparently first carbonised on a commercial scale, for the production of coke, at the iron works of the Prince of Nassau-Saarbrucken at Sultzbach, and a detailed description of the process is given by the French author, de Genssane who had made a personal inspection of the plant, in a book published in Paris in 1770. In addition to the production of coke, the coal tar was also recovered, but no one seems to have thought of using the gas, which must often have taken fire and blazed on a very large scale. The results of experiments on the distillation of coal were also published by Watson in 1781, and in the same

[1] Vol. 41, pp. 59-61.

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year this question occupied the attention of the Earl of Dundonald. Another very early worker about this period was Minckelers, who, in 1784, investigated the possibility of using gas for balloons.

The real originator, however, of the gas process, and the first man who systematically carbonised coal and other vegetable matter with the definite object of obtaining illuminating gas, was William Murdock. He was born in 1754 in the village of Lugar in Ayrshire, the son of a small farmer, and his remote ancestors are said to have been of Flemish extraction. He was of an inventive turn of mind from a boy, and seems to have experimented at a very early age in heating shale in an iron pot, there being a small outcrop of shale in his father's cabbage garden. A cave is shown to this day where these early experiments are said to have been carried out. Murdock left his native village in 1777, when he was 23 years of age, and obtained a situation as a mechanic with Messrs. Boulton and Watt in Birmingham. It is not known when he actually commenced his experiments on the gas process, but by 1792 his work in this connection was in full swing, in spite of his busy life among the Cornish mines, and he lighted his house at Redruth with gas during this year. He used for his experiments a cylindrical iron pot set in brickwork over an open fire in the yard of his house. This pot held about 15 lb. of coal, and was closed at the top by a lid and provided at the side with a delivery pipe, the crude gas being burnt merely at the end of an open pipe, until the accidental use of an old thimble with a hole in it, discarded by his wife, resulted in the substitution of a burner formed like a thimble perforated with a number of small holes. In this way Murdock systematically carbonised a great number of vegetable products, not only many varieties of coal, but also wood and peat, estimating the yield in each case.

Unfortunately his employers, Messrs. Boulton and Watt, were not enthusiastic, and tried to dissuade him from continuing the work, and Murdock seems at one time at have thought of leaving their employment on this account. Boulton relates that on one occasion when visiting Cornwall, he accidentally met Murdock about to enter a London coach, and persuaded him to abandon the journey. Murdock stated he was going to look for mechanics, but Boulton felt certain he was really going to London to try and find people to help him financially with his gas project.

Murdock, however, could not be turned away from his gas process, and he is said, in 1797, to have lighted a house at Old Cumnock in Ayrshire, where he was staying. The following year he left Cornwall for good to take up a permanent position at the Soho works in Birmingham; his own account is as follows:—

"In the year 1798 I removed from Cornwall to Messrs. Boulton, Watt and

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Co.'s works for the manufacturing of steam engines at the Soho Foundry, where I constructed an apparatus upon a larger scale, which during many successive nights was applied to the lighting of their principal building, and various new methods were practised of washing and purifying the gas. These experiments were continued with some interruption until the peace of 1802, when a public display of this light was made by me in the illumination of Mr. Boulton's manufactory at Soho on this occasion. Since that period I have, under the sanction of Messrs. Boulton, Watt and Co., extended the apparatus at Soho Foundry, so as to give light to all the principal shops, where it is in regular use, to the exclusion of all other artificial light."

As soon as he got settled down at Soho Foundry, Murdock began to experiment systematically with many different kinds of cast iron retort to get over the difficulty of extracting the fused mass of coke. For bulk gas production he used a cast iron pot form of retort, fitted inside with an iron cage holding about 15 cwt. of coal. When the carbonisation was completed, the cage containing the residual coke was lifted out with a small crane and replaced with another cage of coal. In 1805 Murdock utilised this form of retort in equipping the first factory, apart from that of Boulton and Watt's establishment in 1802, with gas lighting, that of Messrs. Phillips and Lee's cotton mill in Manchester, which was fitted with a complete gas plant and 900 gas burners, in addition also to lighting Mr. Lee's private house.

The burner used by Murdock at this time was a closed tube with holes at the end, based on his original thimble burner, but subsequently in 1808 he invented the "cockspur" burner, having three tiny divergent jets merging into one flame giving about one candle-power per cubic foot. Murdock gave a paper on this installation before the Royal Society of Arts in 1808, and was awarded the Society's Rumford Gold Medal. The paper contains a simple and lucid account of the results obtained. The cost of the production of the gas was £650 per annum, using a mixture of 110 tons of cannel coal at 21s. per ton and 40 tons of ordinary coal at 10s. per ton, and the 900 gas burners gave a better light than candles at 1s. per lb., costing the mill £2,000 per annum. However, Boulton, Watt and Co. were still not particularly enthusiastic, being finally only stirred to action by the advent to London of an individual named Winsor.

Murdock seems to have soon arrived at the horizontal retort with a section of the shape almost identical—except as regards size—with the fireclay horizontal retorts in use to-day. Some of these retorts were also of the "through" variety, that is, they could be opened at each end, and the sizes he used varied from 3ft. to 7ft. in length and 12in. to 20in. wide.

Fig. 1, Plate XII., represents one of the installations at Soho Foundry reputed to have been erected by Murdock, but at what date the author was unable to

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state. The retorts are in settings of three, direct fired underneath, with the stand-pipes from each retort going to the hydraulic main across the top of the setting and with special arrangements for cleaning the tar out of the pipes. Fig. 2 shows the gas-holder as used by Murdock with this installation, which was actually in use until 1910, latterly for producer gas[3].

We must now turn to France, where, about 1791, an investigator named Lebon, an engineer in the service of the French Government Department of Bridges and Roads, had commenced experiments with the carbonisation of saw-dust, and produced a brilliant illuminating gas. This work was carried out quite independently of that of Murdock, and in France Lebon is rightly regarded as one of the originators of the gas process. Lebon seems to have worked on very similar lines to Murdock, completing most of his work by 1799, and eventually he created a public sensation in France in 1801 by lighting his house in the Rue St. Dominique, Paris, with gas. The fame of these demonstrations spread through the Continent and attracted the attention, among others, of a German named Winsor, Winzer, or Wintzler, who was born in Moravia. This Winsor, as he is generally called in English literature, travelled specially from Frankfort to see the demonstration, and apparently tried—without success—to come to some business arrangement with Lebon. Winsor then seems to have experimented himself until he discovered the method of making gas from coal, and subsequently came over to London with the object of developing a heat and light company for the manufacture of gas, because, as he wrote in one of his pamphlets: "the thought of introducing the discovery for the advantage of the British realm struck me like an electric shock."

He took up his quarters in 1806 at the Star and Garter Hotel, 97, Pall Mall, a site now occupied by the Carlton Club, and his efforts to establish the gas industry by means of lectures, demonstrations, and pamphlets caused an undoubted sensation. If the statements made by Lady Bessborough, writing on September 7th, 1807, to the Earl of Granville, are true, one can well believe it. According to this lady, Winsor promised a return of 6,000 guineas a year for every seven guineas subscribed, and 17,000 shares were sold in ten days, the price rising from par at one guinea to seven guineas per share, with every prospect of rising to 100 guineas per share, whilst Pall Mall was blocked with people in carriages, on horseback, and on foot, rushing to invest. The good lady, who apparently had the misfortune to hold a lot of shares, began to be dubious, and wrote concerning the scheme that "it would probably involve half England in ruin, me among the rest, and prove a second South Sea bubble."

Winsor gave in his own pamphlets a most elaborate but incomprehensible

[3] These photographs have been kindly supplied by Messrs. Avery, who occupy the old works. The gasholder is still in existence.

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balance-sheet, showing apparently that an annual return of £64 10s. 0d. was to be expected from every £6 expended, and talked about "1,000 per cent. being saved and gained in heat, light, and some valuable products for British manufacturers, commerce and navigation."

One of his advertisements in 1807 stated: "Official experiments prove one chaldron of coals to contain £23 2s. 0d. in value, which gives about £242,000,000 for the yearly consumption of the realm. The estimated savings are only rated at £114,845,294, all costs of carbonising, &c., deducted, and if the company only realise one-tenth of this reduced sum, each £5 deposit will secure to the subscribers £570 per annum."

Winsor's frenzied appeals were in striking contrast to the simple and lucid statement of Murdock in 1808, and he also backed his opinions with poetry more appalling than his balance-sheets, the following being an example:

"Must Britons be condemned for ever to wallow
In filthy soot, noxious smoke, train oil and tallow:
And their fumes for ever to swallow.
For with sparky soot, sniffs, and vapours men have constant strife,
Those who are not burned to death are smothered during life."

It is charitable to assume that Winsor was a lunatic, but at any rate he lighted part of Pall Mall with gas on January 28th, 1807, the first public thoroughfare in the world to be so illuminated. Winsor used as a retort an iron pot with a lid luted on and an outlet pipe in the centre, on the lines of Murdock, and he passed the crude gas through a condenser consisting of a circular conical cistern, broader at the bottom than the top, divided by a series of perforated plates, the object being to purify the gas by spreading it out and separating a little of the tar. The whole of the ammonia, sulphuretted hydrogen, carbon bisulphide, and other poisonous impurities of course remained in the gas; hence it is not surprising that the audience at Winsor's popular lectures on the gas process suffered from violent headache, which created a prejudice against gas. Winsor was subsequently lucky enough to engage a man named Samuel Clegg, who had been a mechanic with Boulton and Watt, and worked as assistant to Murdock in most of his gas experiments at Birmingham. Clegg was able to improve the process considerably, and in 1806 lime was used to purify the gas partially, which was first bubbled through water, as Murdock had done, and then passed through lime and water. It would appear that this use of lime was first suggested by William Henry, of Manchester, the well-known chemist. At this very early period the gas pipes used were of lead and the burners of copper. Winsor finally got his Heat and Light Company started, the capital of £50,000 being over-subscribed, and he then applied for a charter to the House of Commons. There was violent opposition to this application, particularly by Boulton, Watt and Co., on behalf of Murdock, as the original

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inventor, although, as already seen, they themselves had done very little to help the process. The Bill was subsequently thrown out, but another Bill was introduced at the next session, and passed finally into law on June 9th, 1810.

In 1812 the London and Westminster Chartered Gas Light and Coke Company received a Royal Charter of Incorporation and became subsequently the present Gas Light and Coke Company. The first Chief Engineer of the Chartered Company was Samuel Clegg, who was a man of very great ability and can justly be regarded among the pioneers of the gas industry and second only to Murdock. Clegg, presumably under Murdock's direction, had lighted a cotton mill in Halifax with gas in 1805, and had also erected other gas plants at Manchester, Coventry, and Hyde. After his appointment as Chief Engineer, which undoubtedly saved the company, he invented in 1809 an improved wet lime purifier, the first gas meter in 1815, the wet gas meter with a revolving drum in 1816, and also—as will be discussed later—several types of continuous retort. Clegg's gas meters, however, were not a practical success until they were improved by John Malam, who also invented the first dry gas meter in 1820. This John Malam may also be regarded as one of the pioneer gas engineers, starting as a draughtsman at the Peter Street Gas Works in 1817, and in addition to his work on the gas meter, he also improved very considerably the retort settings, and devised an improved combination of three wet lime purifiers. The Chartered Gas Light and Coke Company, in addition to many practical troubles, very soon had to face severe competition, and in 1814 the South London Gas Company (afterwards the Phœnix) started, followed in the same year by the City Gas Company, which opened a gasworks in Fetter Lane. There was, however, such an uproar about this because of the smell and the general nuisance that in 1815 they were compelled to remove to Blackfriars. The gas industry made the terrible mistake at this early stage of building their gasworks in thickly populated neighbourhoods. The Chartered Gas Light Company had, for example, its first works in Peter Street, Westminster, and Brick Lane, St. Luke's. This meant that extravagant prices had to be paid for land when extensions were required, and that ruinous charges were incurred for the conveyance of the coal, which was brought up the Thames, mainly from Newcastle, in barges and had to be all unloaded by hand into small carts and conveyed to the gasworks. It was this foolish choice of sites more than anything else that saddled the gas industry with difficulties and prevented it from being a commercial success, the Chartered Company, for example, paying no dividend until 1817. Also the gas companies were, quite rightly, in continual serious trouble because of the intolerable nuisance caused by these early gasworks, and the gas industry of that time certainly had very little regard indeed for the community in the matter. In addition to the general foul smells given off —and even a modern gasworks is not very pleasant in this respect—the gas was

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purified in wet lime purifiers, and the stinking lime cream residue from the purifiers, known popularly as "blue billy," was carted continually through the streets, creating a serious nuisance. In 1817 Reuben Philips, of Exeter, invented the dry lime purifier, but the gas companies refused to adopt this clean, simple and efficient system until they were forced, by threatened legal action, to do so eleven years afterwards. In addition, the nuisance caused by gasworks throwing bad smelling gas water and tar into steams, rivers and sewers was a serious matter, and did much to convert many of our beautiful rivers into little better than open sewers.

The early history of the gas industry altogether makes extraordinary reading. The first gas pipes used were of lead or wood, and cast iron was also suggested, being first tried in 1810. Mostly, however, old gun barrels were employed, screwed into one another, and when in 1825 wrought iron pipes were introduced by Whitehouse, these were known as "gunbarrels" in memory of their predecessors. By 1816 about 15 miles of main gas pipes of various sorts and sizes had been laid in London, Clegg's first mains for the Gas Light and Coke Company being only 2in. diam.

About 1820 the price of gas was something like the equivalent of 15s. to 20s. per 1,000 cubic feet, and even then was one-third to one-fourth the cost of oil lamps for an equal light. By 1829 there were over 200 gasworks in the United Kingdom, and the price of gas in London had been reduced to about 12s. per 1,000 cubic feet.

The gas industry, however, continued to experience great difficulty in making the process pay, and was always struggling to improve the yield of gas by increasing the temperature of carbonisation. By about 1845-1850 this temperature was the maximum the cast iron retorts would stand, about 1,400 deg. Fah. (760 deg. Cent.), under which circumstances one ton of good Newcastle coal gave about 8,000 cubic feet of gas, a big improvement, although the gas was somewhat reduced in quality, and the coke more difficult to ignite because of the reduced amount of volatile matter. The melting point of cast iron is about 2,000 deg. Fah., and the wear and tear on the retorts, even when protected by fireclay shields, was ruinous. The average life, with great care, did not now exceed about eight to nine months under the best conditions, and at a carbonisation temperature of over 1,475 deg. Fah. a very few months was sufficient. The price of these retorts was also very high, about £6 to £7 per ton, and the retorts meant a cost of 6d. to 7d. per 1,000 cubic feet on the gas.

For high temperature carbonisation the cast iron retort was doomed, and the obvious material was fireclay, as used to-day, which was the original material adopted by John Grafton in 1820. Grafton erected his first retorts at Cambridge Gas Works in 1824, consisting of square ovens built of firebrick, holding 4 to 5 cwt.

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of coal at a time, an enormous increase as compared with the small cast iron retorts. These new retorts had a number of advantages. In the first place the temperature of carbonisation was raised without difficulty to 1,750 deg. Fah., which caused a complete revolution in the gas process. The yield from one ton of Newcastle coal was increased to about 8,750 cubic feet of gas and very soon temperatures of 2,000 deg. Fah. were attained, with a yield of 9,500 cubic feet, whilst the composition of the gas was altered considerably, with formation of benzene hydro-carbons due to "cracking" of the paraffins. The life of the retorts was very satisfactory, the first installations lasting over six years at the much higher temperature, whilst the quality of the coke was excellent.

As already stated, the introduction of the fireclay retort was a revolution in the gas industry, and inaugurates what may be termed the intermediate stage of gas manufacture, whilst at the same time the price was being gradually brought down, being, for example, in 1849 an average of 6s. per 1,000 cubic feet in London. More experience with fireclay retorts and still higher temperatures enabled the gas yield to be increased to 10,500 cubic feet per ton of Newcastle coal, and by about 1860 a more or less standard gas of sixteen candle-power was adopted for London.

There are still a number of other points of interest in connection with the early history of the gas process. In 1856 the famous chemist, W. H. Perkins, discovered the first aniline dye mauveine, when trying to synthesise quinine from the organic compound aniline. This led to a new source of revenue for the gas industry, and a use for the particularly obnoxious waste product, coal tar, since aniline is made from benzene, one of the constituents of tar, so that the tar distillery industry dates from this time.

It was soon realised by Murdock himself that for the best quality gas coal must be carbonised in thin layers so as to prevent the richer constituents of the gas from being decomposed in struggling though a red hot mass of coke. The idea of a continuous carbonisation must have appealed to inventors almost from the commencement, and in 1815 Clegg patented various continuous retorts in which the coal was carbonised in thin layers. One of these retorts was of rotary design, provided with shallow boxes attached to radial arms rotating round a central shaft. The coal was charged into the trays at the cool side of the retort and the tray of coke subsequently removed, carbonisation taking place on the heated side of the retort. Clegg also invented a web retort, in which coal was carried on an endless chain and carbonised in a thin layer as it travelled through the carbonisation chamber; but all these earlier continuous retorts were abandoned, chiefly because of the excessive wear and tear.

The vertical gas retort was the original invention in 1828 of John Brunton, the brother of William Brunton, and embodied in his patent 5712/1828. John

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Brunton has received very little credit indeed for his remarkable invention, which, apart from the retort being of cast iron, anticipated in an astonishing fashion not only the modern vertical intermittent retort, but a number of other refinements in the working of gas retorts.

William Brunton was engaged by Boulton and Watt in 1796 as a mechanic, and in 1802 was appointed superintendent of the Soho engine yard, a separate establishment of the Soho Foundry. It was whilst in this position that he apparently engaged his brother John as a mechanic. At any rate, John was also an employé of Boulton and Watt for a number of years, and along with Samuel Clegg assisted Murdock with his gas experiments at the Soho Foundry. William Brunton left the firm in 1807 when he went to the Butterley Iron Works. In the Science Museum, South Kensington, there is an original letter from him dated April 28th, 1813, addressed to his brother John who was then in Belfast, his address being "c/o Mr. J. Rider, Belfast Foundry, Belfast." This letter was written whilst William was still at Butterley, but unfortunately gives no clue as to what John was doing in Ireland. When the patent for the vertical retort was taken out, John Brunton was Chief Gas Engineer at West Bromwich.

Apparently John Brunton erected his vertical retorts at West Bromwich, and ran them for a number of years, but nothing further is known about them except that the early text-books on gas manufacture simply state the idea was found to be impracticable, without giving any reason, the same idea being tried in 1829 by Barnet.

Brunton seems to have invented also a mechanical charging mechanism for horizontal retorts, which certainly worked at West Bromwich for a number of years, until he retired, when it was abandoned. This appliance consisted of a hopper holding 20-28 lb. of coal and piston working through a stuffing-box and propelled by a double-threaded screw which charged the retort once every hour, the time for charging being six seconds. The red-hot coke at the other end of the retort was discharged into water, and Brunton stated that 35 per cent. more gas was obtained by this process than by the ordinary method. One of the difficulties, however, seems to have been that the tar was absorbed by the coke and thereby rendered unsaleable.

In 1855 Rowan carbonised coal in a cupola, the coke being taken out intermittently at the bottom through a water seal, but the gas industry would not consider anything but the horizontal retort and the vertical retort consequently lapsed entirely.

It was not until 1902, that is seventy-four years later, that the vertical retort came to life again with the work of Settle and Padfield at Exeter, patent 12,252/1902, and later on in the same year the patent of Dr. Julius Bueb, of Dessau, in Germany, 15,154/1902. These were intermittent retorts, and in 1903

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Woodhall and Duckham took out the first patent for a continuous vertical retort. The history of the vertical retort in general use is of course outside the scope of this paper, but it is only fair that the pioneer genius of John Brunton should now be recognised. It is a remarkable fact also that William Brunton has never received the true recognition of his great genius. For example, the short biography of William Brunton in the "Proceedings of the Institution of Civil Engineers," from which the account in the "Dictionary of National Biography" is copied, never even mentions his epoch-making invention of the practical mechanical stoker.

With regard to the use of gas, it will have been realised that the whole process of gas manufacture originated entirely to supply gas as an illuminating agent in competition with candles and oil, and until quite recent years this was the chief function of gas. But by about 1851 a few gas-cookers were used in hotels and restaurants, following on the great exhibition at Hyde Park in that year, when a number of gas stoves were exhibited. The development of gas cooking was, however, very slow in the early period of the gas industry.

Gas was first used for gas fires for the heating of rooms about 1840, and what may be termed the modern gas fire was patented by Edwards in 1849, whilst the first gas water-heater was that of Robert Hicks, in 1825, but no real development was made in this direction in the use of gas until about 1890.

The Author read his paper in abstract prefacing it by saying that in looking back over the period under review one could not help being struck by the amazing amount of work that was done by the pioneers of the industry, much of which bore little fruit and was not appreciated at the time. The struggles these men had to overcome opposition; the apparent lack of imagination in choosing sites for gas-works where the price of land was enormous, throttling the industry and preventing any return upon the capital invested till about 1825 in spite of the high prices charged for the gas; the waste in operation and distribution and the muddle were almost incredible. The entire change that had come over the industry in that gas was used for heating rather than for illuminating could only be alluded to.

The paper was illustrated by photographs and prints, some of which have been reproduced in the text.

The President moved a hearty vote of thanks to the Author, which was carried by acclamation.

Discussion.

Mr. W. J. A. Butterfield said he had nothing but praise for the paper; the Author had given a more striking history of the gas process than any previous writer he knew. He noticed there was no reference to Accum's *Treatise* with its illustrations of gas plant, also designs for gas fittings, pendants and brackets.

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The early gas engineers were not progressive, but they had to fight against great prejudice and were hampered in every way, e.g., in laying mains in the streets. Gasworks in those days were certainly most undesirable neighbours. As indicating the scale of plant used, he believed that in 1812 the Royal Society recommended that no gas-holder should exceed 5,000 cubic feet capacity. The Author had not, of course, referred to the recent progress made, but it was safe to say that at the present day gas engineering was as up-to-date as that in any other industry. The Author had mentioned the recent change over from lighting to heating, and he might state that 75 to 80 per cent. of output is now used for purposes other than lighting.

Mr. Samuel Glover said the paper was useful and authentic. They were indebted to the Author for having brought out so clearly the invention of the vertical retort and John Brunton's right to the credit for it. Too much must not be claimed for him, however, as his retort was intermittent; the modern one that was so successful was continuous. He doubted the Author's statement that Murdock had handled at one time as much as 15 cwt. of coal in his cast-iron pot retort; he suggested that the correct figure was probably more like a tenth of this. The speaker gave some interesting facts as to the extent and output of the present gas industry.

Mr. H. W. Dickinson mentioned that the house at Redruth where Murdock carried out his experiments had recently been damaged by fire. The speaker enquired what was the type of gas fire used for heating apartments before 1849.

Mr. W. J. Tennant said the Author had explained how gun barrels came to be used for gas pipes, hence when wrought iron welded pipe was introduced it was known, and is still known, as "gas barrel."

Mr. G. W. Cussons, commenting on the lack of foresight displayed by the early gas engineers, said they were not alone in that respect; the same thing occurred for example at the inception of the electric light industry. He enquired how the gas was measured in the very early days.

Professor P. M. Baker said that Murdock's house at Sycamore Hill, Birmingham, presented the first instance of domestic lighting; the gas was led from Soho some little distance away. Murdock's gas-holder, in his opinion, had done more for the world than hundreds of generals and admirals.

Mr. Norman Swindin admitted that little scientific knowledge was employed in early gas-making; it was empirical and traditional. It had, however, changed and was now perhaps the most scientifically conducted of any industry; indeed, he would call it the basic industry after agriculture.

Mr. A. Benham and Mr. G. F. Zimmer also spoke.

The Author, in reply, said that the discussion had strayed somewhat from the standpoint of his paper, which was the *early* history of the gas process, say,

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prior to 1850, and the strictures that he had passed upon the industry applied only to that period. He was cognisant of the information given in Accum's *Treatise*[3] but was unable to make use of it in such a short paper. The statement that a charge of 15 cwt. of coal was used in his cast-iron pot was Murdock's own.

The early gas fire was an imitation of a coal fire, not the radiation type of to-day. As regards measurement of gas, this was a real difficulty before Clegg's invention of the gas meter in 1815; contracts were entered into with persons to supply them with gas between certain hours for a fixed number of burners; in other words, the supply was on a kind of rating basis.

[3] Illustrations, however, have been taken from this work (*see* plates XIII. and XIV.). [Ed.]

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Notes on Sir George Cayley as a Pioneer of Aeronautics.

By J. E. Hodgson.

(Read at Prince Henry's Room, Fleet Street, May 23rd, 1923.)

In his address on the aims and objects of the Newcomen Society, delivered by our first President at Birmingham in 1921, some idea was afforded of the manifold and varied phases of engineering history and industrial development, in both ancient and modern times, which come within the scope of the Society's researches. The address is one the purport of which we shall do well to recall from time to time. It is true there was no mention in that address of the subject—a subject the earliest aspects of which date back many hundreds of years, and which is to-day fraught with significance not even yet fully realised—with one chapter of which this paper deals. The omission may perchance reflect the notable neglect from which the history of aeronautics has heretofore suffered. It is because that neglect has been so plainly revealed in the course of some years study of aeronautical history, that I have attempted the following elucidation of the work of a great English pioneer in the field of aeronautical science and engineering—Sir George Cayley. I would add that the following notes on his aeronautical writings and experiments make no pretensions to fulness, but are offered as a preliminary contribution to the more adequate appreciation of his work.

The subject of this paper may be dealt with conveniently under three headings: First, a brief summary of Cayley's life and character; second, an account of his work on navigable balloons; and third, a like account of his work on mechanical flight. The latter sections will be prefaced with a short survey of the state of those two branches of aeronautical science up to the period of Cayley's youth. It should, perhaps, be added by way of introduction that Cayley's place as a pioneer in aeronautics has not yet been fully assessed. His name is barely mentioned in that over-rated and cumbrous compilation *Astra Castra,* published by Hatton Turnor in 1865, and it is a notable omission from the *Dictionary of National Biography.* In English aeronautical histories—for the most part regrettably unscholarly and inadequate—the comprehensive character of Cayley's work is usually overlooked. Indeed, with the exception of the excellent reprint

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of the essay on "Aerial Navigation"—dealing mainly with mechanical flight—published in 1910 by the Royal Aeronautical Society as the first of a series of *Aeronautical Classics*, Cayley's writings—notably his investigations into the problems underlying navigable balloons—are not readily accessible. On the other hand, his work—to which so able an advocate of mechanical flight as Alphonse Pénaud fully admitted his indebtedness—is more frequently mentioned in terms of respect by French writers, but their accounts are inevitably incomplete.

Cayley's Life.

Sir George Cayley—the only son of Sir Thomas Cayley, and the sixth baronet since the creation of the title in 1661—was born at his ancestral home, Brompton Hall, in the North Riding of Yorkshire, on December 27th, 1773. The bent of his mind towards scientific pursuits became apparent in his early years, and it is said that his interest in aerial navigation—"a noble art," as he subsequently termed it—was inspired, when he was not more than ten or twelve years old, by the Montgolfiers' invention of the balloon. As he himself relates, his first experiment in aeronautics was made with a Chinese "flying top" in the year 1796, and it is significant of his steadfast attachment to the subject that as late as 1854 he sent a description of an improved type of this aerial toy to the distinguished French aeronaut and writer, Dupuis-Delcourt. On the death of his father, in March, 1792, he succeeded at the early age of twenty to the family estates. In 1795 he married Sarah Walker, the only daughter of the Rev. George Walker, F.R.S., and President of the Literary and Philosophical Society of Manchester, by whom he had a large family, the members of which in later years were taken for extended tours to France and Italy. As a young man Cayley was influenced—like Wordsworth and many more of his contemporaries—by the outburst of the French Revolution, Horne Tooke and Tom Paine being numbered among his friends: He took an active part on the Whig side in county politics, and officiated for many years as President of the York Whig Club. But though inspired with warm feelings in the cause of liberty, he was not drawn into sympathy with any unconstitutional proceedings, and, in the spirit of a true Englishman, he took his part as the commander of a corps of volunteers when Napoleon threatened this country with invasion. His first published contributions on "Aerial Navigation" (mechanical flight) appeared in Nicholson's *Journal of Philosophy* in 1809-10; in 1816-17 he expounded in the pages of Tilloch's *Philosophical Magazine* his ideas on navigable balloons, a subject to which he returned later in letters published in the *Mechanics' Magazine* in 1837. Further contributions (suggested by the discussion on Henson's "Aerial Carriage"), made to the latter periodical in 1843, with an unfinished article in the *Bulletin* of the *Société Aérostatique et Météorologique de France*, in 1853, complete the record of his extant writings on aeronautics.

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From information obtained two years ago by the present writer from Mrs. Thompson, who, as a grand-daughter of Sir George Cayley, spent a considerable part of her childhood at Brompton, it cannot be doubted that these published writings cover but a small part of all the investigations, calculations, and experiments made on aeronautical matters over many years, and it is a matter of great regret that Cayley's notebooks and papers cannot now be traced.

Of his life and scientific labours apart from aeronautics little is known, though some idea of his inventive ability as an engineer may be gathered from contributions to the *Mechanics' Magazine* (*see* Bibliography at the end of this paper). Politics and the affairs of his family estates doubtless occupied much of his time, but it is clear that his chief concerns were science and engineering in general, and aeronautics in particular. He is said to have been one of the first promoters in modern times of extensive drainage schemes in Yorkshire—notably at Murton—and Lincolnshire, while he was also one of the earliest advocates of the cottage allotment system. Mainly for the purposes of his work in aeronautics, he built a shed or outhouse at Brompton, in which he conducted a large number of experiments on the application of electricity as a motive power, and on the development of the caloric or hot air engine. In the latter connection it should be added that some years prior to 1807 Cayley had projected a caloric engine (designed at that time to obviate the drawbacks of the steam engine, which had "hitherto proved too weighty and cumbrous for most purposes of locomotion"), but though constructed at Newcastle on what he termed "a considerable scale," it proved unsuccessful.[1]

Later in life he accepted the congenial office of chairman of the old Polytechnic Institution. In 1852 he stood successfully as Parliamentary candidate for the borough of Scarborough; but at his advanced age the duties and responsibilities of a Member of Parliament must have proved arduous, and it has been suggested that he only entered Parliament in order to draw public attention to a subject which, rightly, and with remarkable foresight, he realised to be of the greatest importance to this country and to civilisation at large. He is not known, however, to have found opportunities of impressing his views on the House in the two years he remained a Member before retiring. He died at Brompton Hall on December 15th, 1857.

Of Cayley's character it is difficult, from the meagre knowledge available, to form a true conception. I regret that it is not possible to do so, for as one whose studies have mainly concerned men of letters and men of action, I appreciate the value of a just and lively estimate of a man's character, as a help to under-

[1] In a paper read before the Civil Engineers in 1853 it was said that Cayley's "caloric engine was the first to approach a practical design," while Goldsworthy Gurney expressed the opinion that "the air-engine may be said to have originated" with Cayley.

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standing his work and aims. From the little we know of Cayley, I imagine that his temperament and environment tended to make him a genial country gentleman —one blessed with ample means, with a family to rear and educate, an estate to manage, and local affairs to engage some measure of his time—rather than to develop an engineer or a scientist, whose whole life was destined to be sternly devoted to one or other of those fields of endeavour. At the same time I feel that the late Sir Walter Raleigh, in the necessarily brief account of Cayley contained in the introductory chapter to his *History of the War in the Air,* was a little depreciatory in suggesting that Cayley merely " amused his leisure with science," as also in his remarks that Cayley " put nothing on the market " and was " content to enunciate a truth and to call it probable." For Cayley's work was seriously undertaken, though I gather he had no ambition to earn rewards, either material or otherwise.[2] He himself disavowed any desire " to scramble "—as he called it—for any share in the credit, at that time too often mistakenly attached to the invention of aerostatic machines, " save only," he significantly added, " that of braving the risible muscles of my friends by substituting *acres* for *yards* of cloth in their structure." Indeed, the moderation he exercised in setting forth his ideas—the mark of a certain measure of greatness—affords a sharp contrast to the assurance frequently displayed in contemporary ballooning projects. Nevertheless, he sought to encourage the work of others—his criticisms of Henson's " Ariel Carriage " and Luntley's " Rotary Balloon," for instance, were studiously moderate in tone and were directed towards the technical difficulties of these projects, at least the former of which he urged as " undoubtedly true in theory."

Moreover, in his own eagerness to acquire information, he carried on a considerable correspondence with scientists and inventors of his day, both at home and abroad. I have also read that it was due to Cayley's generous financial help that his friend, Baron de Ferussac, was enabled to start the publication of the *Bulletin Universel.* One can only add that the amplitude of Cayley's views on aerial navigation suggests a mind of great breadth of view, endowed with remarkable imaginative foresight. For as early as 1809 he expressed complete confidence in the practicability and security of mechanical flight as a method of transport, at a speed exceeding that of the railway train, and by 1816-17 he was advocating the navigable balloon with even stronger conviction, as offering " a direct, swift and easy floatage from any one point to every other on the face of the globe." His large conception of air travel cannot be more forcibly expressed than in his own words: " An uninterrupted navigable ocean," he said, " that comes to the thres-

[2] According to Mrs. Thompson, Cayley deliberately refrained from any attempt to exploit the commercial value of his ideas on aeronautical or other machines. He took out only two patents, viz., No. 5260 (6th October), 1825, New locomotive apparatus (an early design for caterpillar traction), and No. 7351 (25th April), 1837, Apparatus for propelling carriages on common roads (embodying an early anticipation of mechanical stoking).

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hold of every man's door, ought not to be neglected as a source of human gratification and advantage."

STATE OF CONTEMPORARY AEROSTATIC SCIENCE.

I pass on to outline, as briefly as possible, the development of the science of aerostation, particularly with regard to the direction or control of balloons, up to the time when Cayley first turned his attention to the subject. It is well-known that the balloon was invented by the Brothers Montgolfier in 1783, and that in October of that year Pilâtre de Rozier first ascended into the air in a balloon of the Montgolfier type—that is a balloon inflated with hot air rarefied by means of a fire burning in a brazier. In the following December this method of inflation was improved upon by J. A. C. Charles, who introduced the use of hydrogen. After hundreds of years of aspiration and fruitless endeavour, these aerial achievements were naturally regarded with wonderment and gave rise to extravagant hopes of utility in the service of man. But it was realised almost at the outset that the use of the balloon as a method of aerial travel would be greatly limited, unless it were possible to devise a method of control. The case was aptly put by a contemporary versifier in four lines:—

"To Montgolfier the invention's due
Unfinished as it lies,
But his will be the glory
Who direction's art supplies."

Hence arose countless schemes, mostly emanating from France, designed to accomplish that obviously desirable object. By a natural but erroneous process of inventive thought, the false analogy of the boat sailing on the water and steered by a rudder, was followed in the earliest projects. An early design embodying the sails and rudder principle was that of Thomas Martyn, a natural history draughtsman, who published in London an engraving of his "Aerostatic Globe," which he claimed to have originally designed in November, 1783. Such suggestions can have served no other purpose than that of making clear the apparent lack of what was then commonly termed a "point d'appui," and, as a corollary, the need of applying a propelling force. Oars or wings, consisting of a light framework covered with silk or other material, were the first forms of mechanism designed to afford manual propulsive power, J. P. Blanchard, in March, 1784, being the first to experience—though not to admit—their inefficiency. Other projects tried or suggested were forms of jet propulsion (by means of hot-air, on the principle of the æolipile of the ancients), or by the reaction of gunpowder exploded in the form of rockets. Yet another method—invented by David Bourgeois in 1784, which also engaged the attention of Montgolfier in France, and at a slightly later date of R. L. Edgeworth and Cayley himself in Great Britain—involved the use

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of an adjustable plane surface fitted beneath the balloon, whereby to obtain some measure of control from the pressure of air on such plane during the rise or fall of the balloon. Of the great majority of these early schemes, it need only be said that they were faulty in theory or futile in application. An important exception must be made, however, in the case of the theoretical examination of the principles involved, undertaken by J. B. M. Meusnier, equally distinguished in military, scientific and mechanical achievements. As early as December, 1783, he prepared a memoir in which he suggested the need of making the form ellipsoidal, and introduced the use of the air ballonet. It is probable, however—and I am indebted on this point to my friend Colonel Lockwood Marsh, Secretary of the Royal Aeronautical Society—that Meusnier erroneously conceived the ballonet as a means of height control rather than for the purpose it more truly serves in modern practice—namely, to preserve the shape of airships of the non-rigid type. But Meusnier's work and the drawings and plans which were made in connection with it are very remarkable, as well in respect of form and the ballonet, as in his ideas of diagonal rope suspension of the car and in the application of airscrews—worked, of course, by manual power—for propulsion.[3] The airship—it deserves to be so termed, if only for the fact that it was designed to be 260 feet in length—was never constructed, and the only contemporary test of the ballonet principle was in its profitless application to the elongated free balloon of the Brothers Robert, in which they made ascents during July and September, 1784. An air ballonet was, however, incorporated in the design of a "fish-formed" balloon invented in 1789 by Baron Scott, a French officer, who may possibly have taken his idea of shape from the so-called "Flying Fish" aerostatic machine, exhibited in Cornhill in 1785, which (according to the attribution of Isaac Reed) was the work of Samuel Hoole, son of Samuel Hoole, watchmaker and mechanician, and brother of Dr. Johnson's friend, John Hoole. Incidentally, it may be added that Johnson not only gave expression, at an early date, to doubts on the utility of the balloon—"a species of amusement," as he characterised the invention in a letter to Dr. Brocklesby, "for I do not find that its course can be direct, so as that it should serve any purpose of communication"—but he agreed that wings would not assist as a means of direction. Scott's ideas more probably inspired S. J. Pauly, a Genevan gunsmith, who actually constructed a "fish-formed" dirigible which he tried with some measure of success at Sceaux in 1802, deriving an inadequate propelling power from the use of wings or revolving oars. In 1815 he came to London, and with financial help of Durs Egg, a noted London gunsmith, the "Dolphin Balloon" was commenced at Kensington, a sum of over £10,000 being subsequently expended on the construction. The project has a slight in-

[3] A set of Meusnier's designs in water-colours is preserved in the admirable collection of aeronautical exhibits (Collections de l'Aéronautique) at Chalais-Meudon.

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direct connection with Cayley—whose published writings on dirigible balloons it preceded—inasmuch as it led him to realise the great expense of such ventures, and hence the impracticability of experiments on "an efficient scale of magnitude" by private enterprise. The envelope—about 90 feet long—was made of layers of gold-beaters' skin, and it was to contain an air ballonet 21 feet in diameter, horizontal stability being maintained by means of an adjustable weight suspended between the tail of the balloon and the car. A more important feature was the intention to obtain "the propelling impetus" from "a kind of atmospheric steam engine, invented by Mr. Collier." But financial and other difficulties proved insuperable, and "Egg's folly," as it was called by the cynics, was never completed. It represents, however, in the main, the stage the navigable balloon had reached in Cayley's day, the chief features being the shape—tending towards streamline—the air ballonet to preserve that form, the suspension of a gondola or car beneath the envelope, and the suggested use of steam as a prime mover.

It will, of course, be appreciated that the foregoing remarks are but the merest outline, and, moreover, that there were many aspects of the problem which, in those early days, had received but small consideration at the hand of the pioneers. These men aimed primarily at using the principle, the "floatage" as Cayley called it, of the balloon, as an aeronautical device, and by a modification of the original shape and the application of motive power, rendering it capable of direction and control, thus converting it into a machine fitted for the purpose of aerial navigation. The highly complex and multifarious questions in physics, mechanics, metallurgy, and so forth, with which to-day the airship designer and constructor have to deal, were, perhaps fortunately, beyond the ken of the pioneers. They strove with such elementary knowledge as they possessed to do no more, but no less, than drive and steer a balloon through the air—an achievement which was not actually accomplished until 1852, when Henri Giffard, in an elongated balloon fitted with a steam engine of three horse-power, obtained an independent speed of six miles per hour.

Cayley's Work on Navigable Balloons.

Coming to Cayley's own work on dirigible balloons it has been already mentioned that his first published essays on the subject appeared in Tilloch's *Philosophical Magazine* during 1816-17. It is true that his earliest writings on aeronautics dealt with mechanical flight, but I take his contributions to "lighter-than-air" theory first, because his ultimate faith in the success of aerial navigation over the world's surface was based on the possibilities of the navigable balloon. He made this clear beyond dispute in one of his last letters on the subject. He pointed out that it had been proved—to use his own words—on "tolerably well-ascertained data," that elongated balloons of a large size were capable of being

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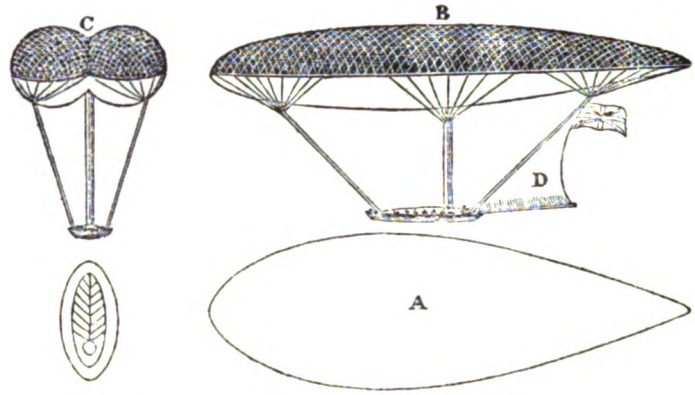

Fig. 1. CAYLEY'S HOT-AIR DIRIGIBLE BALLOON, 1815.

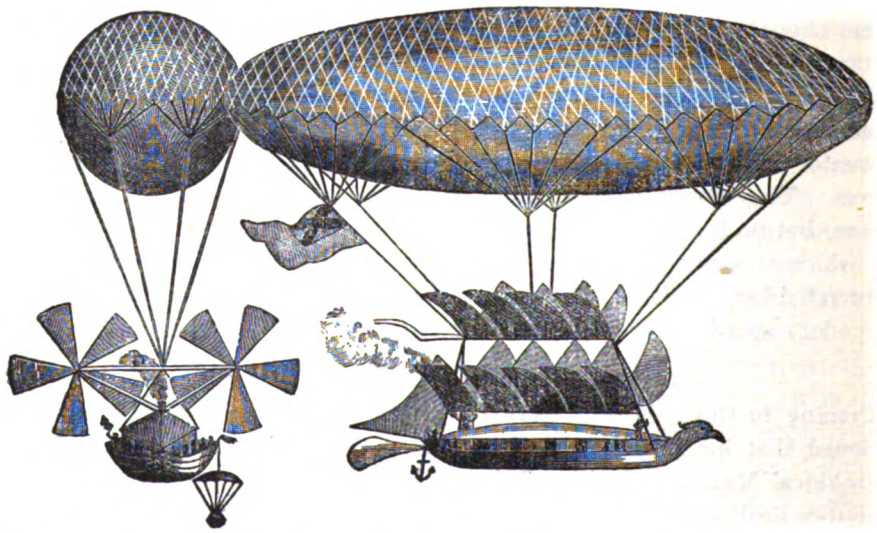

Fig. 2. CAYLEY'S DIRIGIBLE BALLOON (with wing and screw propulsion respectively).

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driven through calm air at a speed approaching that of the railway train, and could carry a considerable cargo by reason of their buoyancy. From these premises he argued that " on a great scale, balloon floatage offers the most ready, efficient and safe means of aerial navigation." " Elongated balloons of large dimensions," he wrote in the same paper, " offer greater facilities for transporting men and goods through the air, than mechanical means alone, inasmuch as the whole weight is suspended in the air without effort . . . and when the invention is realised, it will abundantly supply the increasing locomotive wants of mankind." Moreover, in the sentence immediately following he gave prophetic utterance to the view which, after much ebbing and flowing, has in quite recent years received the support of distinguished aeronautical experts—the view that the relation of airships to aeroplanes is complementary and not competitive. " Mechanical flight," Cayley wrote in 1843, " seems more adapted for use on a much smaller scale, and for less remote distances; serving, perhaps, the same purpose that a boat does to a ship, each being essential to the other."

Broadly speaking, it was Cayley's ability to grasp the basic scientific or mechanical principles underlying the theory of navigable balloons, rather than his skill as an inventor or designer, wherein lies his true greatness as a pioneer of the airship. He was, for instance, one of the first to realise fully the practical significance of the main factor on which airship theory rests—namely, the physical law that " the surfaces (and hence the resistance) increase as the squares of the diameter of the balloon, whereas the capacity to contain gas (and hence the supporting power) increases as the cubes of the diameter." If it were not for that principle he knew quite well that the difficulties would be far greater; or, as he himself put it, " we must be contented to give up balloons for purposes of locomotion altogether, or to attempt them on that scale of magnitude which a well-grounded calculation of their power proves to be necessary." As to the factors involved in the question of resistance, he pointed out (as indeed others had already done) that obviously the spherical form of the ordinary free balloon should be lengthened horizontally, thus diminishing the cross-section for the same volume, and he realised the desirability of dividing the gas into several compartments—as he said, " like the stomach of a leech." With more originality he even suggested that dirigibles, " when used as permanent vehicles and on the true scale of magnitude, will probably be made of thin metallic sheets kept firm by condensation [that is pressure] with separate light bags of gas within." For a first experiment on these lines he suggested that Charles Green's large balloon —presumably the famous " Nassau Balloon " of 1836—should be requisitioned, and that two other balloons of smaller size should be " packed at opposite sides of this larger one," a suggestion which, however, was not tried. Of greater

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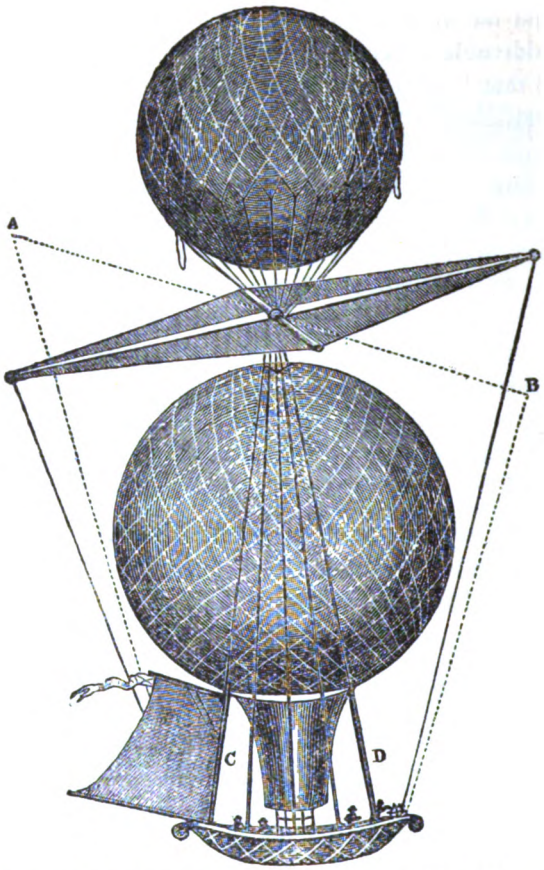

Fig. 3. CAYLEY'S COMBINED HOT-AIR AND GAS BALLOON, 1837.

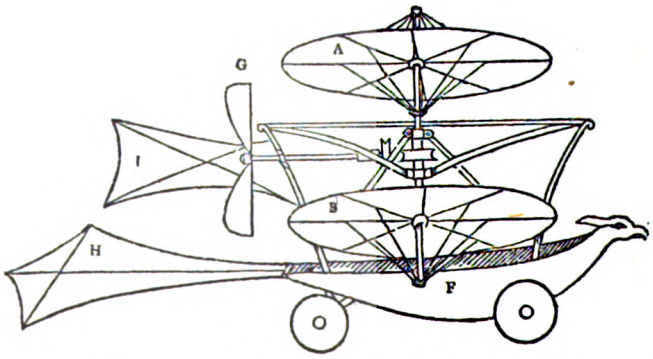

Fig 6. SIDE ELEVATION OF CAYLEY'S AERIAL CARRIAGE, 1843.

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interest is his early anticipation of some degree of rigidity, revealed in the proposal to guard against the then unknown laws of resistance offered by fluids to solid bodies, by means of "light poles and internal cross bracings of wire or cord," designed to preserve the shape of his elongated spheroidal balloon. Moreover, Cayley carefully considered the problems affecting the transmission of power from an engine suspended in a car beneath the envelope to the balloon itself—a point of particular moment in his own design owing to the need of keeping the boiler and furnace of the steam engine which he proposed to fit as far as possible below the envelope. As to his "prime mover," he had perforce to adopt the steam engine, but he clearly realised it was by no means an ideal form of power for the purpose, and there is reason to believe that his experiments, both with gas engines and electricity, were largely inspired by the idea of turning those sources of energy to account in aeronautics.[4] With regard to the fabric of the envelope, which necessitated, as Cayley laid down, a material "perfectly air-tight, light and strong," he suggested that the great expense of silk (covered with india-rubber varnish) would be prohibitive, and proposed as an alternative "double-cotton Indian-rubber cloth," as invented in 1823 by Charles Macintosh for waterproof garments and air-tight cushions. In this particular it is of interest to note that Cayley's work was not wholly theoretical, for in 1816 he refers to a cloth weighing ½lb. per square foot as used in "my experiments."

It is not possible within the limits of this paper to enter on any full account of Cayley's designs for a navigable balloon. It must suffice to give some indication of his ideas in general, and the calculations (in all cases quoted from his own writings) on which they were based. In his first design, as communicated (with accompanying plans) to Tilloch's *Philosophical Magazine* in 1816-17, he provided for a Montgolfière or hot-air balloon 300ft. long, 45ft. in elevation, and 90ft. wide, made of "woollen cloth." In form it was an elongated spheroid, with a conical head and a slight tapering towards the stern—on the axiom common among sailors, that a ship to sail well should have a "cod's head and a mackerel's tail"—and it was to be kept to its shape by the light poles and cross bracing before mentioned. (Fig. 1.) Professor Raleigh has remarked on the soundness of Cayley's ideas on what is now known as the doctrine of streamline, but he points out that though Cayley realised that the shape of the hinder part of a solid body travelling through the air is of as much importance as the shape of the fore part, he does not seem to have known that it is actually of more importance. In the first design the impelling power was to be derived from the deviation obtained from the pressure of air on a passive plane surface, a wholly inadequate

[4] Mrs Thompson retains a distinct recollection that Cayley's interest in other forms of motive power than steam was prompted by the idea that they might prove efficient for aeronautical purposes.

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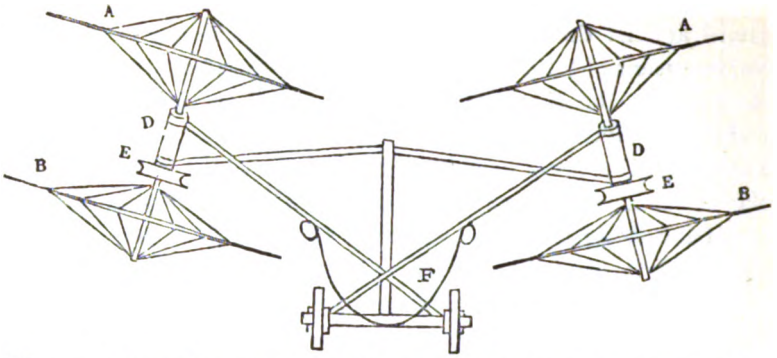

Fig. 4. END ELEVATION OF CAYLEY'S AERIAL CARRIAGE, 1843.

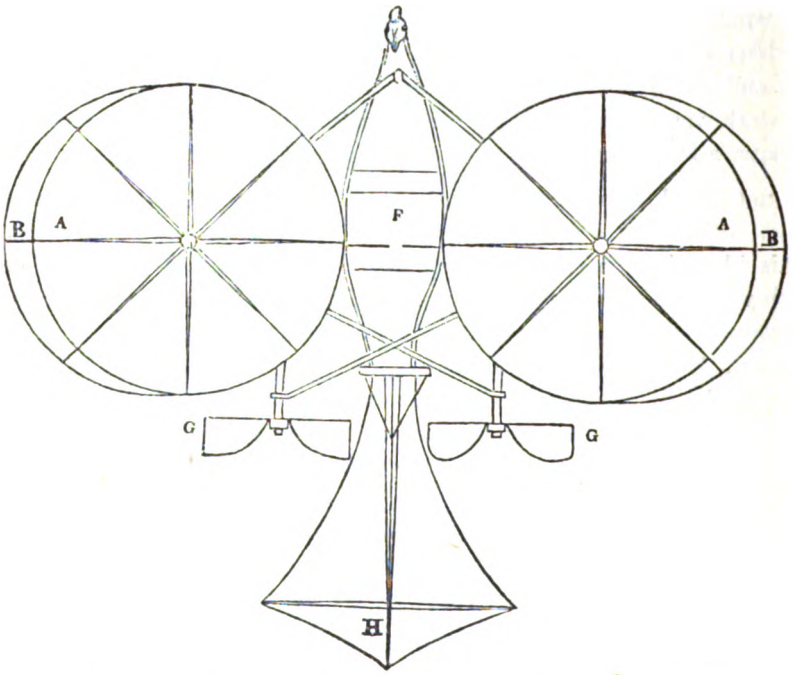

Fig. 5. PLAN OF CAYLEY'S AERIAL CARRIAGE, 1843.

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method, the idea of which, as Cayley admits, was derived from the plan described by John Evans a year earlier. In his next essay, Cayley goes beyond his original ideas, and offers calculations based on the possibility of propelling an elongated hydrogen balloon by wing waftage—that is, wings fitted to the sides of the car and actuated by a steam engine. He expressed a preference for this (mistaken) form of propulsion as against "rotary wafts" or airscrews, mainly owing to the difficulty of "giving firm support and communicating motion to the latter," though admitting the advantage they afforded of uniform action. This improved design was to be 144ft. long, with a lift of 163,000 lb., which reduced by the weight of the materials (1,700 lb.) and of the engine, boiler, fuel, etc. (15,210 lb.), would leave about 34 tons. Stated in terms of performance, Cayley estimated that this would allow of the transportation of 50 men for 48 hours, or a voyage of 960 miles in calm air. Further consideration of this "balloon of 50 tons" led him to comment on the difficulties involved in the "stupendous bulk" difficulties arising from expenses of construction and inflation (he estimated hydrogen to cost £300 a ton, though looking to a reduction by the application of new methods of production) and difficulties in "disposing of them when not employed." He does not appear to have contemplated the construction of immense airship sheds, such as have been erected in recent years, for he made calculations on the "horizontal drag" of large balloons at anchor, from which he deduced that this drag diminishes with size and oblong structure. Indeed, at a later date he laid down that "permanently-filled balloons would ride out storms when properly secured, without the danger of being driven to earth or damaged."

In 1837 he revised the foregoing speculations in a lengthy communication to the *Mechanics' Magazine*, wherein he sought to present considerations which would be "most conducive at present towards a final accomplishment of the aerial object in view." His elaboration of the "inclined plane" method of propulsion —of which he offered what he called "a rough and hasty sketch" by way of an experimental plan—involved the combination of a large Montgolfier below and a smaller hydrogen balloon above, separated by the plane. But apart from the danger of such a combination—a danger experienced with fatal results in 1785 by Pilâtre de Rozier—the method was not worth even the brief consideration Cayley gave to it. Moreover, the twenty years or so which separated his essays had resulted in improvements in the steam engine, which by 1837 gave promise of greater power in proportion to weight. In this connection Cayley referred to the steam carriage of his friend Sir Goldsworthy Gurney (he wrote of it in 1837 as "recently completed"), the engine of which he calculated would give one horse-power for 200 lb. weight. But though he recognised that "lighter first movers than steam engines may be discovered, and made applicable to propelling balloons," he proceeded to take the case as he found it. With a hydrogen balloon

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of a similar shape to his original design, 90ft. in diameter and 315ft. long, he estimated there would be available for engine power, crew and cargo, a lift of about 29¼ tons. He further estimated that a balloon of this size, bearing a strong resemblance, as he put it, "to a hundred-gun ship," would require an engine of 60 horse-power.

As to the application of propelling power, he still adhered to the idea of wings arranged in two tiers (Fig. 2), but he also reverted to the idea of airscrews—"oblique vanes," as he said, "reversing the action of the sails of a windmill." (Fig. 2.) As to the latter, he instanced the results of experiments made by the French Academy, which went to show that "a proper fulcrum or resistance for the engine power to work upon can be had at a velocity of 25 feet per second." Finally, reckoning the engine, with fuel and water for four hours, at 510 lb. per horse-power, and deducting also the weight of the "machinery for waftage," Cayley arrived at the conclusion that travelling at the designed speed of 14 miles per hour his balloon would have a useful load of about 9 tons.

Cayley never attempted the construction of a large navigable balloon, but we may well believe he was only deterred by reason of the great expence. This difficulty led him in 1817 to suggest experiments by public subscription, an appeal he renewed in 1837 in the form of a proposal to organise a "Society for Promoting Aerial Navigation." It was doubtless the indifference shown towards his proposals that led him to write in 1843—in words which, with some modification, are even to-day not wholly inapplicable to the prevailing attitude towards the airship—"I think it is a national disgrace in these enlightened locomotive times not to realise by public subscription the proper scientific experiments, necessarily too expensive for any private purse, which would secure to this country the glory of being the first to establish the dry navigation of the universal ocean of the terrestrial atmosphere."

Contemporary Ideas on Mechanical Flight.

Turning to the general conceptions of mechanical flight in Cayley's time, and the ideas which had led up to them, it may be said at once that there were only two points of view—the one from which flight was regarded as a matter of flapping wings, and the other as a matter of impossibility any way. The old, the very old idea of wings, was doubtless inspired by the natural, not to say obvious, analogy of the flight of birds. The practicability of mechanical flight was first expressed by Roger Bacon in the middle of the 13th century, while early in the 16th century the idea occupied the great mechanical genius of Leonardo da Vinci. Indeed, broadly speaking, it is true to say that flight was invariably regarded in the light of the imaginary achievement credited by Francis Bacon to the inhabitants of his *New Atlantis*, 1627. "We imitate also the flight of

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birds," says the sage, in a marvellously prophetic recital of countless mechanical devices and scientific notions practised in that utopian community. Those words held good for something like the next two hundred years, not only, indeed, as an expression of aims, but as a baneful conception which blocked other fields of speculation. For that reason it is unnecessary to enter into any detail, or to recall the endeavours—more numerous, probably, than is commonly realised—made during the 18th and 19th centuries to achieve flight by means of wings. Even in the years immediately preceding the discovery of the balloon, J. B. Blanchard was engaged in futile and fruitless attempts to construct a "flying vessel" actuated by wings. Moreover, it was the alleged success in 1809 of Jacob Degen —a watchmaker of Vienna—with a flapping-wing machine, that elicited Cayley's first exposition of the true principles of mechanical flight. Not that the study of the principles involved in bird flight was in itself profitless; on the contrary, Lilienthal himself regarded it as "the basis of aviation." But up to Cayley's day, and long after, those principles were not understood; they gave rise to the most varied and unsound speculations, and the blind attempts made to imitate nature diverted attention from the more strictly mechanical aspects. It is because Cayley was amongst the first to approach the problems of flight from the mechanical and not, so to speak, from the ornithological point of view, and because he first conducted "gliding" experiments on a considerable scale, that he deserves to stand among the great pioneers of aviation in the direct line between such names as Leonardo da Vinci in the 16th, and John Stringfellow in the 19th century.

Cayley's Work on Mechanical Flight.

It has been seen that Cayley's first experiment in such matters was made as early as 1796 with a Chinese or aerial top (identical with the device exhibited before the French Academy of Sciences in 1784 by Launoy and Bienvenu), which served at once to illustrate the principle of the helicopter and the airscrew. Though but a toy of a few inches in length, its capacity to demonstrate certain elementary but important principles in aeronautics made a lasting impression on Cayley's mind, and (as already mentioned) only three years before his death he sent to Dupuis-Delcourt a drawing of one which he had made—the best, he said, that he had ever seen, capable of rising 90 feet in the air.[6] Having collected a body of "facts and practical observations in the course of much attention to the subject"—to use Cayley's own words—he published his first essays "On Aerial Navigation," dealing with the subject wholly from the point of view of mechanical flight, in the pages of Nicholson's *Journal* during 1809-10. The character of his

[6] The "Description of an Improv'd Chinese Flying Top," which the drawing illustrates, is now in the Patent Office Library (Autograph Collection, No. 4847), while one of the actual helicopter tops used by Cayley is still in the possession of Mrs. Thompson.

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observations and experiments is at once shown in his ability to grasp essential principles. His reflections on bird flight led him to the belief—confirmed by so great an observer as Charles Darwin nearly 25 years later—that flying required less exertion than was then commonly supposed. But he categorically denounced the idea of flight by means of wings (worked by muscular effort) as ridiculous. In his clearly expressed conviction that mechanical flight was possible, and in his enunciation of the " whole problem " as contained in the simple but comprehensive formula, " To make a surface support a given weight by the application of power to the resistance of air," he is revealed as the earliest true pioneer of the aeroplane. He had perfect confidence in the practicability of transporting passengers and goods—the latter word is expressive of his large ideas—" more securely by air than by water, and with a velocity of from 20 to 100 miles per hour."

His earlier experiments in aerodynamics had revealed (the figures quoted are Cayley's calculations) that a surface of one square foot moving at a velocity of 11.538 feet per second generated a resistance equivalent to 4 oz., or at 17.16 it gave 8 oz. With such inadequate data—obtained by an early form of " whirling table "—he proceeded to make " gliding " experiments, carried out over a number of years, on what he called " a considerable scale of magnitude "—apparently with a machine having a surface of 300 square feet—and his enthusiastic description of one of the trial flights made from the high ground behind Brompton Hall may be quoted not only as the first of its kind, and therefore historic, but also as in itself of great interest. " It was beautiful," he wrote in November, 1809, " to see the noble white *bird* sail majestically from the top of a hill to any given point of the plain below it, according to the set of the rudder, merely by its own weight, descending in an angle of about 18 per cent. with the horizon." Cayley states that the upward lift of this " gliding " machine was at times so strong that anyone running forward in it against a light breeze would be raised from the ground for " several yards together." One trial of the kind gave rise (as related by Mrs. Thompson in a letter to the present writer), to an amusing episode. Cayley had instructed his coachman to run with one of the gliders down the side of the hill at Brompton. Lifted off his feet, the coachman was carried across the little valley and " came down with a smash." When Cayley (fearful of some injury to his servant) hurried to the spot, the coachman indignantly exclaimed, " Please, Sir George, I wish to gi' notice. I was hired to drive, not to fly." Incidentally, it may be added that Mrs. Thompson remembers at a later date seeing one of these gliders relegated to the ignominous and ironic use of serving as a roost for the hens in the chicken-yard at Brompton.

But even as early as 1809-10 Cayley's thoughts were engaged on the question of propulsion, or the necessity of a " first mover." Realising that a steam engine

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of the type invented by Boulton and Watt would not be adaptable, he looked more hopefully (as in the case of his navigable balloon) to the development of some such engine as was reported to have been designed by William Chapman of Newcastle—an early form of internal combustion engine, with oil of tar as fuel. Evidently he intended to make some trial of a " propelling apparatus " with his " glider," for he refers to the fact that an accident (possibly the one abovementioned) prevented his doing so. He continued however, to consider many other factors involved in mechanical flight—problems dealing with questions of initial velocity, the leverage of the wings, and the need for lightness in construction combined with strength. The latter he suggested for the first time might be achieved by designing superposed surfaces, as now usual in the biplane. The wings he conceived should be supported by " diagonal bracing "—which he termed " the great principle for producing strength without accumulating weight "—while he foreshadowed the necessity for streamline design in the maxim, that " in the art of aerial navigation every pound in direct resistance that is done away, will support 30 lb. of additional weight without any additional power." Moreover, Cayley's experiments led him to realise the importance of concave wings—unlike Henson, who designed the planes of his " Ariel " as flat surfaces—and, more significantly, that the centre of pressure verges towards the leading edge of a plane propelled through the air—" a remarkable circumstance," as he said, " that experiment alone could point out."

On the publication in 1843 of particulars of Henson's " steam carriage," he returned to the subject of mechanical flight, and further explained his ideas in two letters to the *Mechanics' Magazine* in April of that year. His criticism of Henson's scheme, though accompanied at the outset with an expression of encouragement, clearly indicated his reasoned doubts as to its success. In the first place " the magnitude of the proposed vehicle," involving a terrific stress on the necessarily light structure of the main supporting surfaces or wings—150ft. span and 30ft. chord, as designed—afforded ground for serious misgivings. The stress or " leverage " on the wings Cayley again suggested might be overcome by securing the required surface not " in one plane, but in parallel planes one above the other," and he went so far as to propose a tri-plane, or " three-decker " as he termed it, an idea revived by Wenham in 1866, and adapted by John Stringfellow in his famous triplane model of 1868. Moreover, while expressing his conviction " that the inclined plane, with a horizontal propelling apparatus, is the true principle of aerial navigation by mechanical means," Cayley doubted Henson's ability to provide the " very great engine power—the *sine qua non* of the case "—which the design required.

As in the case of navigable balloons, Cayley's design for an " aerial carriage " (which he described in the same paper) is hardly as interesting, and certainly not

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as sound, as his examination and discussion of theoretical principles. His plan shows that instead of obtaining the required supporting surface by means of rigid horizontal wings, he proposed two sets of superposed circular planes (designed when in motion to act as helicopters) set at an obtuse angle, and revolving in contrary directions. These circular planes he termed " elevating fliers " to distinguish them from two smaller horizontal airscrews for propelling the machine. The " framing " or fuselage was to be covered with canvas at once to increase the surface and afford protection to the engine, while a " broad horizontal rudder or tail " was designed for use in ascent or descent, and to act as a stabilising " elevator " in flight, with a small vertical rudder for lateral guidance.

Conclusion.

In conclusion, though it be true that Cayley, unlike other pioneers of mechanical inventions, " put nothing on the market," I do not think this fact should be allowed to detract from his merits. After all, to Shakespeare at least, the conception and cultivation of an idea was of far greater significance than any deeds which might spring therefrom. Moreover, though it is not easy to assess the influence of Cayley's experiments and theoretical writings, it may surely be allowed that his ideas were in the direct line of true progress, and led to ultimate accomplishment. It has been said by an authoritative French writer, Alphonse Berget, that Cayley's name deserves to be recorded " in letters of gold at the beginning of the history of the aeroplane." Whether it might not fitly be so written at the beginning of the modern history of aeronautics is a matter of opinion. In any case it will, I think, be generally agreed that it deserves to be writ large and in imperishable ink on the roll not only of England's, but of the world's great aeronautical pioneers[6].

Discussion.

The President, in moving a vote of thanks to the Author, which was carried by acclamation, remarked that the paper was important because it concentrated attention on the work, too often neglected, of Sir George Cayley on Aeronautics.

The discussion was opened by Colonel Lockwood Marsh, who said he thought Mr. Hodgson had chosen a peculiarly appropriate subject for the first subject on the history of aeronautics before the Newcomen Society, because Sir George Cayley had been aptly described as " the Father of British Aeronautics." Though his heavier-than-air researches had been accorded full recognition, this was the

[6] M. Charles Dollfus—whose wide knowledge of aeronautical history in both ancient and modern times is probably unrivalled—recently expressed to the author the opinion that Cayley deserves an even higher place as a pioneer of aeronautics than is claimed for him in this paper.

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first time that his work on the problems of dirigible balloons—or airships as we now call them—had been adequately dealt with. Moreover, he was one of the very few—even down to the present day—who had studied both types of aircraft, and he had extraordinarily advanced views on the relative spheres of the airship and the aeroplane.

Cayley's inclined plane method of propulsion mentioned in the paper reminded him of a small engineless airship which was designed during the Great War to travel without a pilot over the enemy's lines to drop propaganda. The setting of the elevators provided the equivalent of Cayley's inclined plane, and it was a most interesting sight to see this diminutive airship leave the ground and travel forward at a speed of some eight or nine miles an hour without any means of propulsion other than the lift of the gas and the elevators. Another point of interest mentioned by Mr. Hodgson was Cayley's appreciation of the necessity for reinforcement of the nose of an airship to prevent deformation at high speeds. Not only had he been proved abundantly right in this, but the actual method of stiffening suggested by him was used in an airship built for mooring experiments in 1918.

In conclusion, he congratulated Mr. Hodgson on his paper, and desired to thank the Newcomen Society, on behalf of the Royal Aeronautical Society, for according the latter body permission to print the paper in the Journal. The Royal Aeronautical Society had reprinted Cayley's writings on the aeroplane,[7] and they would now be able to have in their transactions an account of his airship work also.

Mr. E. Wyndham Hulme, who took the chair when the President withdrew, referring to the fact that Cayley does not appear in the Dictionary of National Biography, thought that a copy of the paper should be sent to the Editor of that publication, suggesting that Cayley's life should be included in a future supplement. He thought that Mrs. Thompson's evidence on Cayley, alluded to by the Author, should be incorporated in the paper. Mr. Brownlie also joined in the discussion.

In a brief reply, the Author said he had already called the attention of Professor H. W. C. Davis, of Manchester (who is supervising the revision of the Dictionary of National Biography) to the omission of Cayley's name—and those of other notable pioneers in aeronautics. With regard to the information obtained from Mrs. Thompson, he undertook to incorporate these notes as far as possible in the paper before it was printed in the Transactions.[8]

[7] Aeronautical Classics: No. 1. "Aerial Navigation," by Sir George Cayley. 1910.
[8] This has been done.—Ed.

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CORRESPONDENCE.

Mr. W. Worby Beaumont drew attention to the fact that between 1845 and 1850 Lord Carlingford—" mad old Carlingford "—carried out gliding experiments near Ballyragget, Co. Kilkenny, where he had a mound specially made for the purpose.

Mr. Rhys Jenkins wrote that he was glad to see that Cayley had been chosen as the subject for one of the Society's papers. He noted that the Author confined himself to Cayley as a pioneer in aeronautics, and there was scanty evidence that he had tested his ideas on a practical scale. He wondered whether the Author had thought of going behind the material in print by approaching the present Baronet, Sir Kenelm, to find out whether Sir George had not left behind him notes and papers as to what he had done. It was reasonable to believe that he could not have done very much on the large scale, however. He was a large landowner who did a vast amount of drainage work on his estates; besides he is said to have experimented in or investigated the rotary engine, the hot air engine, the application of electric power and optics. Mr. Jenkins submitted to the meeting a little book—presumably rare—indicating the diversity of Cayley's interests. The publication contains reprints of three of his contributions to the *Mechanics' Magazine*, the first is a " Description of an Artificial Hand," the second is on " Aerial Navigation," and the third is a " Means of Preventing Railway Accidents."

Mr. Orville Wright wrote: " Cayley was a remarkable man. His articles in " Nicholson's Journal " in 1809-10 show an understanding of the subject of aerodynamics hardly exceeded by any one except Lilienthal during the rest of the century. I notice in his paper Mr. Hodgson attributes to Cayley the suggestion of using superposed planes. I wonder how widely his letters in the *Mechanics' Magazine* of April, 1843, were read. I believe the credit for the idea of superposing surfaces has generally been given to Wenham."

Mr. Hodgson in reply wrote: Referring to Mr. Orville Wright's interesting notes on my paper, it may perhaps be as well to quote Cayley's own words (as printed in the *Mechanics' Magazine* for April 8, 1843) on the point raised about superposed planes. Remarking on the " terrific " leverage on the wings of Henson's proposed monoplane flying machine, he said, " This consideration shows, that in order to obtain a sufficient quantity of surface to sustain great weights in the air, the extension ought not to be made in one plane, but in parallel planes one above the other at a convenient distance, so as to form a more compact fabric, with less extent of leverage. . . . If, therefore, so large a surface be contemplated for trying this experiment, would it not be more likely to answer the purpose to compact it into the form of a *three decker*, each deck being 8 or 10 feet from the other, to give free room for the passage of air between them? "

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As to how far Cayley's aeronautical studies were known, I gather from frequent contemporary references (usually in terms of high appreciation) that his articles were widely read at the time—at least by the comparatively small circle of men interested in the subject. Moreover, Wenham himself in his classic paper on "Aerial Locomotion" (Aeronautical Soc., June, 1866) quoted from Cayley's earlier articles (Nicholson's *Journal*, Vol. 25, 1810), while at a later date (as above mentioned) so notable a pioneer of heavier-than-air flight as Alphonse Penaud fully admitted his indebtedness to Cayley's ideas.

APPENDIX.

BIBLIOGRAPHY OF CAYLEY'S CHIEF AERONAUTICAL WRITINGS.

1.—On Aerial Navigation [Mechanical Flight], Nicholson's *Journal of Philosophy*, vol. 24, 1809, p. 164, and vol. 25, 1810, pp. 81 and 161.

2.—On Aerial Navigation [Navigable Balloons], Tilloch's *Philosophical Magazine*, vol. 47, 1816, pp. 81 and 321, and vol. 50, 1817, p. 27.

3.—Practical Remarks on Aerial Navigation [Navigable Balloons], *Mechanics' Magazine*, vol. 26, 1837, p. 417.

4.—Retrospect of the Progress of Aerial Navigation, *Mechanics' Magazine*, vol. 38, 1843, p. 263, and On the Principles of Aerial Navigation, vol. 38, p. 273 (both on Mechanical Flight).

5.—Governable Parachutes, *Mechanics' Magazine*, vol. 57, 1852, p. 241.

6.—Mémoire sur le Vol Artificiel [Wing-Propelled Gliding Machine], Société Aérostatique et Météorologique de France, *Bulletin*, No. 4, 1853, p. 147. This paper was intended as a first part only, but the *Bulletin* was discontinued after No. 4. An earlier issue (No. 3, Mai, 1853) contained translations into French of the "Retrospect" and "Principles of Aerial Navigation" before mentioned (4).

The above papers are in each case illustrated with diagrams. The three papers in Nicholson's *Journal* (1) were reprinted in the Aeronautical Society's *Annual Report* for 1876, and again as *Aeronautical Classics*, No. 1, 1910; also in Means' *Aeronautical Annual* for 1895, p. 16. The "Practical Remarks" (3) were reprinted in *Aeronautics*, vol. II, 1909, p. 142, and vol. III, 1910, p. 1. Cayley also contributed short letters on Pauly and Egg's Dolphin Balloon to Tilloch's *Phil. Mag.*, vol. 47, 1816, p. 394, and on Luntley's Rotary Balloon, *Mechanics' Magazine*, vol. 55, 1851, p. 292.

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The Preservation of Historic Buildings and Ancient Monuments.

By Sir Frank Baines, C.V.O., C.B.E,

(Delivered at the Guildhall, Rochester, June 21st, 1923.)

It is unnecessary to urge upon the Members of a Society like yours the importance of preserving our Ancient Monuments—you are all, I know, in sympathy. The interest displayed by the general public in such activities is, however, of recent growth, but it is increasing, and your Society may and should do much in fostering it; it is in this hope that I address you to-night.

It is necessary first to make clear what we understand by preservation—we do not mean restoration, which connotes the replacement of what has decayed or perished, but we mean arresting decay and the retention of what is left in a sound condition as far as practicable, for later generations to see. The work of the craftsman of bygone days is too rare to be added to or taken away from. It is this method that has been adopted by His Majesty's Government in the Department in which I have the honour to serve, indeed the method has the advantage that it involves comparatively much less expenditure than restoration; hence the funds at our disposal, sadly too small as they are, enable a wider field to be embraced.

The Act under which these Monuments are protected is the Ancient Monuments (Consolidation and Amendment) Act, 1913. The Act is strictly limited in scope, excluding, for instance, dwelling houses and ecclesiastical buildings still in use for their original purpose, and while it imposes certain restrictions on the private citizen, it undertakes certain obligations. To put it shortly, monuments and buildings may be handed over to or taken over by the State, and will thereafter be maintained at the public expense. Almost invariably the buildings when taken over are in a condition of great neglect, or perhaps it would be more correct to say active decay, and it is because of this that so many problems arise for solution.

Undoubtedly the most potent agency of disintegration that we have to contend with is vegetation—ivy, shrubs, and even trees—that grow to such a size that they have been known to split masonry for a length of 30 feet and to a width of 18 inches. The negligence that allows ivy to grow over a ruined building from an idea that it is peculiarly in keeping with it—an idea fostered by the sentimental school of poets—can hardly be sufficiently condemned.

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A problem that continually recurs is that where only a part of a building, such as an arcade, remains standing; the original support given by vaulting, arches, buttresses, etc., has vanished. Further, the building frequently is seriously out of plumb, and again the core of the walling may have gone to dust—much mediæval work was careless in respect of hidden construction—hence bulging and cracking is in evidence. It would be not unreasonable to restore the buttresses, vaulting, etc., but this would be contrary to the spirit which animated their work. On the other hand, to add buttresses that were not in the original design, as has been done frequently in the past—would make the judicious grieve, and was inadmissible as a solution by his Department.

The Author then, with the aid of a large number of lantern slides,[1] rapidly reviewed the means that were actually adopted to meet the situations alluded to above in buildings taken over by his Department. Each case had to be carefully studied by itself as to its own special needs after a careful survey, before even a spade was used.

Rievaulx Abbey, Yorkshire, was taken as an example. When handed over, the nave of the conventual church was a mound of fallen masonry. Only the presbytery and the choir with the transepts and the east arch remain (*see* Plate XVI). The spandrel of the S.W. pier of the chancel was particularly dangerous, threatening the existence of the whole arcade. The method adopted was to remove the fractured stones one by one, recore the spandrel and the pier above with reinforced concrete, and finally to replace the old stones. Twelve months later no trace of what had been done was observable. (*See* Plate XVIII.)

Byland Abbey, Yorkshire, another example, was in an appalling state when taken over. The ashlar masonry within reach had been robbed for building purposes, and the stumps of walls, etc., above ground were crowned with ivy. On the removal of the rubbish from the church many remarkable finds were made. Here again coring with reinforced concrete was used.

At Richmond Castle, Yorkshire, some of the masonry was actually sliding downhill, and had to be arrested.

Jedburgh Abbey, Roxburghshire, presented possibly the most serious problem with which the Department has yet had to deal. The tower of the church was definitely giving way, and was only kept up by modern brick piers and by shores, in addition to heavy repairs of earlier date. The Norman piers, while having the appearance of stability and strength, had practically gone to dust in

[1] A paper covering largely the same ground was read by Sir Frank Baines before the Royal Society of Arts on December 12th, 1923, and appears in the Journal of the Society LXXII. 120, to which members who are interested are referred for further information.—Ed.

[2] Some of the photographs shown have been reproduced as illustrations. See Plates XVI. to XIX.

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the core. The suggestion to take down and rebuild the tower was rejected on the grounds already stated, apart from the question of expense. An attempt to grout the piers with cement failed, because the grout refused to be incorporated with the pulverulent core. It was eventually decided to recore the piers and the arches. After heavy centering and shoring, this was accomplished bit by bit. To-day the tower stands, securely carried by its reinforced concrete core; the work was done at a fraction of the cost of rebuilding.

Whitby Abbey, Yorkshire, was a case of a different kind because it had suffered from German bombardment during the Great War. With meticulous care, such of the stones as were not shattered were collected, identified and replaced in position. (*See* Plate XIX.)

An entirely different class of work was that undertaken at Stonehenge. There certain of the sarsen stones in the inner circle were gradually falling outwards. To prevent this a timber jacket or cradle was built round the stone to support it while its foundation was excavated and concreted. The stone was then tilted back into the vertical position and bedded. Some idea of what must have been the task of the neolithic erectors could be inferred from the magnitude of the modern plant required to do this work.

The earthwork known as Maiden Castle, Dorchester, 115 acres in extent, presenting yet another kind of problem, was illustrated. Scars had been caused by the erosion of chalk from the slopes and the loss had to be made good. It was interesting to note that to keep down rabbits from burrowing in the slopes and helping their destruction again, it had been found necessary to appoint a keeper to look after the place.

The Author paid a great tribute to the devoted zeal of the clerks of works, masons and others who had been and were engaged on these tasks.

A short discussion followed, whence it emerged that only monuments of what may be called the first order had hitherto been tackled. There were numberless ruins, not fewest in the part of England where the paper was being given that required attention if they were to be saved from utter disappearance.

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Summer Meeting at Rochester
June 21st and 22nd 1923.

First Day's Proceedings.

Members and guests assembled on Thursday morning, June 21st, at the Institution of Mechanical Engineers, Storey's Gate, S.W.1, and motored to Crayford to visit the old-established fabric printing works of Messrs. G. P. & J. Baker, Ltd. In the absence of Mr. G. P. Baker, who was to have taken the party round, it was met and escorted over the works by the director and manager, Mr. H. Clayton. The old-fashioned hand-block printing process, the designing and cutting of the blocks, the old pattern books, the dyeing and mordanting of the cloths, and finally a large modern rotary 15-colour printing machine was shown. At the conclusion of the visit a vote of thanks to Mr. Clayton was passed by acclamation. It was now noon, and a move was made by the motor for the Royal Victoria and Bull Hotel, Dartford, where lunch was served. At two o'clock the party entrained for Chatham, where, by kind permission of the Admiral Superintendent, a visit arranged through Mr. G. A. Bassett, was paid to the dockyard. Here both the old and the new were in curious juxtaposition, demanding attention; in the first category may be mentioned the rope-making machinery, which was in one of the oldest buildings, and in the second a gyroscopically controlled cruiser; the giant submarine launched a day or two previously and then in dock was seen in the distance.

Dinner at the Bull Hotel, Rochester, followed, the guests of the Society for the evening being His Worship the Mayor of Rochester, Alderman A. E. J. Price; Mr. G. A. Bassett, Mr. Edwin Harris the local antiquary, and Sir Frank Baines, C.B.E., C.V.O., Principal Architect of H.M. Office of Works. Good fellowship prevailed, heightened by punning remarks from the President on the antiquity of the Society and its patron saint, Titleus.

After dinner followed a lecture, open to the public by invitation, in the Guildhall, by kind permission and under the Chairmanship of the Mayor, who had been induced to preside by Mr. Henry F. Wingent, Councillor. The subject of the lecture delivered by Sir Frank Baines was "The Preservation of Historic Buildings and Ancient Monuments."[1] It was illustrated by a series of remarkable lantern slides, showing the work done in this direction by the Department of the Office of Works presided over by the lecturer. The discourse was atten-

[1] A report of the lecture is given on p. 90.

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tively followed and frequently applauded; a discussion followed, concluded by votes of thanks to the lecturer and the Mayor. By courtesy of the latter, who is *ex-officio* Admiral of the Medway, the City Regalia were shown to the members and audience. A hurried glance at the Guildhall itself, dating from the 17th century, was also possible.

Second Day's Proceedings.

The meet took place at the Bull Hotel, where several of the members had been staying the night. A motor was in waiting, which took the party, favoured by glorious weather, to Maidstone. A short halt was made half way, to visit the neolithic cromlech known as Kits Coty, and here the influence of Sir Frank Baines's Department was in evidence, for the monument had been cared for and protected. The motor took the party from Maidstone to the village of Tovil close by and drew up at Hayle Mill, the works of Messrs. J. Barcham Green & Son, where the whole process of making hand-made paper, with every refinement suggested by modern experience, from the sorting of the rags even to the preparation of the size, was going on. The party was received by Mr. Herbert Green and divided into three sections, to go over the works: one under his own guidance, another under that of his son, Mr. J. B. Green, and the third under that of the Manager.

Mr. Green said that the mill was established in 1806 by John Pine, a member of an old Maidstone family still represented in the town; it had then two vats. In 1810 he sold the mill to John Green, a paper-maker whose family had been connected with the trade for several generations; since then the mill has been carried on by members of this family, the present partners being of the third and fourth generations respectively. Steady progress was made, a third vat having been added between 1810 and 1839 and two more between 1860 and 1880. A sixth vat was put in between 1920 and 1921, but owing to depression in trade it has never been brought into operation.

The mill was originally driven by a water wheel, but now steam power is employed; the supply of water for operation is drawn from an artesian well because the purity of the dam water was not found sufficient for the highest qualities.

Mr. Green remarked that while skill and experience are very necessary throughout the operations, the making of the actual sheet of paper is a very highly skilled craft and draws the highest rate of pay. Three men (or two men and an apprentice) are required to work each vat. Several men were seen working whose fathers and grandfathers had preceded them, indeed some of them could trace back their families for quite a long way as paper-makers. For the lighter work

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women are employed, and many of them have been at the mill for a great number of years; one old lady of 80 who entered into conversation with some of the party came to work at the age of eight.

At the termination of the visit, Mr. Green kindly presented each visitor with a souvenir, which took the shape of hand-made paper neatly boxed.

Great Ivy Mill, higher up the valley, was then visited under the guidance of the Manager, Mr. Hilder A. Bowers. Here the manufacture of millboard of various kinds by hand and machine was shown. But the visit had to be cut short, unfortunately, otherwise there would not have been sufficient time for the lunch which was waiting at the Bockingford Arms, formerly the Hand-in-Hand—the Papermakers' Society's emblem. After lunch the return journey to Rochester was undertaken, a visit to a treadmill of 17th century date at Berham, a short distance away from the road, being reluctantly omitted for lack of time.

At Rochester the party was guided over Rochester Cathedral by Mr. Edwin Harris, of the Dickens Fellowship. Permission had been obtained by him from the Dean to visit the Cloisters, not usually seen by visitors. Rochester Castle was next taken, but severely tested the endurance of the party, and only two or three attained to the battlements, the goal of the visit. These visits concluded with a vote of thanks to Mr. Harris.

Thus terminated a successful and enjoyable meeting.

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Notes and Communications.

Savery, Newcomen and the Early History of The Steam Engine.[1]

By Rhys Jenkins.

Part I.

For a considerable period up to the first decades of the eighteenth century the problem of unwatering mines had been a very pressing one in this country. As early as the reign of Elizabeth we find that it was receiving a great deal of attention, and of the 52 patents for inventions granted by that Queen, seven were for apparatus for raising water from mines and for pumps in general. Step by step various improvements were effected in the pumps themselves, and in the mode of operating them; but these improvements failed to keep pace with the increasing demands of the miners. What was required was some new source of power to take the place of animal labour, less expensive, and less limited in capacity.

To two men of Devon—Thomas Savery and Thomas Newcomen—belongs the distinction of satisfying this long-felt want—of giving the miners a new source of power by the application of steam.

Not, be it understood, that they were the first to *propose* to apply steam for the purpose of raising water. It is not intended in this paper to discuss the sequence of inventive ideas which preceded the production of a practical steam engine, but it may be said that whatever arguments may be brought forward, on the one side or on the other, as to the novelty of the principles underlying the inventions of Savery and Newcomen, there is absolutely no question that Savery was the first to produce a practical working apparatus for raising water by steam and to make, and to supply to the public, such apparatus.

Savery, it is true, failed in the complete solution of the task he had undertaken. He produced an apparatus which, while it worked well when used for raising water to moderate heights, was not equally successful for greater heights,

[1] This article is reprinted from the Transactions of the Devonshire Association, 1913, with certain additions from the London Devonian Year Book of 1911, by kind permission of the Council of the Association and of the Editor of the Year Book respectively. It makes an appeal to a wide circle outside that for which it was immediately written, hence no excuse is needed for reproducing it here.—Ed.

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such as occur in pumping in mines. Still, to use the words of the celebrated French philosopher, Arago:—

> "Whatever imperfection the practical success of Savery displays, the name of this engineer deserves to occupy a most distinguished place in the history of the steam engine. Persons whose whole life has been devoted to speculative labours, are not aware how great is the distance between a scheme, apparently the best concerted, and its realisation. It is not that I hold with a celebrated German philosopher that Nature always cries 'No, no!' when we attempt to raise a corner of the veil which hides her; but, to follow out the same metaphor it is at least fair to affirm, that the enterprise becomes more difficult, more delicate, and of more doubtful success, in proportion as it demands both the concurrence of more artists, and the employment of a greater number of material elements; and, as to these various points, making allowance for the period at which he lived, was there ever a man placed in more unfavourable circumstances than Savery?"[2]

It may be the case, however, that his work helped to pave the way for Newcomen, who did succeed in producing an engine which met the demands of the miners and came into use with rapidity, particularly in the coal mines; this engine embodies the cylinder and piston.

The sole problem with Newcomen, as with Savery, was to raise water. Savery did indeed suggest that the water when raised might be allowed to flow over a water-wheel, but this was a suggestion merely. Animal power, wind, and water mills sufficed to meet the demands for power in manufacturing operations at that period, and it was not until a later stage in the evolution of the steam engine that it was adapted for the production of rotative motion. The modern cylinder and piston steam engine, as a machine, has been brought to a high state of perfection; it embodies a vast number of distinct inventions, the labour of many minds, but, whether applied in the locomotive, in the steamship, or for driving in factories, it is nevertheless directly descended from the pumping-engine constructed by Newcomen in 1712.

THOMAS SAVERY.

The earliest distinct reference to Thomas Savery, the engineer and inventor, is of the year 1694, when we find in the State Papers a petition from him praying for the grant of a patent for his inventions for polishing plate glass and for propelling ships. From that date onwards till his death in 1715 a considerable body of material relating to his public life is available. Although the documentary

[2] Historical Eloge of James Watt, by M. Arago. Translated by J. P. Muirhead. 1839. p. 43.

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evidence is not altogether conclusive, there seems to be no doubt that Savery came of a family long established in the south of Devon.

His first biographer, Dr. Rigaud, in 1839, stated that: "He was descended from a family which has been settled for several centuries in the south of Devon, and during that time has formed the most respectable connexions, which has been in possession of considerable landed property, and has given more than one Sheriff to the county. He was probably born in that part of England about the middle of the seventeenth century, but the place and time of his birth are not exactly known. He was by profession a Military Engineer, and the Saverys having been active in promoting the revolution of 1688, were especially noticed by King William the Third.

Mechanics appear to have been his favourite study, and as he pursued them practically, he was able to form a body of workmen to execute his plans."[3]

From the account given in Cotton's *Sketch of the Antiquities of Totnes*,[4] it appears that Christopher Savery of Totnes, who was the grandson of another Christopher, one of two brothers, merchants in Totnes, purchased, about 1614, the manors of Shilston and Spriddlecombe in the parish of Modbury, and took up his residence in Shilston House. He was High Sheriff of Devon in 1619, was knighted, and died about 1622. His son Christopher, who in 1648 was appointed by Parliament one of the Commissioners for raising troops in the County of Devon and made Lieutenant-Colonel in a regiment of foot, had two sons, Servington and Richard. Thomas is said to have been the son of this Richard Savery. Servington Savery succeeded to the Shilston property. In 1685 he became suspected of disaffection to the Government, and an order for his arrest, together with that of his son Christopher and William Savery of Slade in Cornwood, was issued. Christopher Savery, after his father's death in 1689, lived at Shilston; he was appointed Sheriff of Devon, a Deputy-Lieutenant and Colonel of Militia. His son and heir, Servington Savery, died at Shilston in 1744.

Polwhele, in a footnote, refers to him as "a very ingenious mathematician and mechanic; being the inventor of artificial magnets, the diagonal barometer, etc., as is well known among men of science"; and states that Shilston continued to be the family residence of his descendants until the time of his great grandson John Savery, who purchased and removed to Butcombe Court, near Bristol.[5] Shilston is now a farmhouse.

This John Savery, in 1809-10, prepared a history of the family, which remains

[3] Proceedings of the Ashmolean Society, Oxford, 1839, also "The Gentleman's Magazine," 1839, Vol. ii., p. 261.

[4] William Cotton: A graphical and historical sketch of the antiquities of Totnes. 1850.

[5] R. Polwhele: "The History of Devonshire, 1806." Vol. iii., p. 462.

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in manuscript,[6] and it would appear that this was the basis of the account given by Rigaud and, to a large extent, of that given by Cotton. The manuscript contains a transcript of a letter written by Servingon Savery to Dr. Jurin, the Secretary of the Royal Society, relating to his improvements in the barometer and to the preparation of artificial magnets. It is dated "Shilston, Aug. 9th. 1727," and has, for our present purpose, a most important postscript: "The late Mr. Thos. Savery, inventor of the engines for rowing and raising water by fire, was, I believe, well-known to several of the Royal Society and perhaps to the President, but as I am a perfect stranger, I acquaint you that his father was the youngest brother of my grandfather."

This transcript would no doubt be taken from a copy retained by the writer, Servington Savery. The original letter cannot be found among the papers of the Royal Society, but there is no ground for doubting its authenticity and, coming as it does soon after the time of Thomas Savery, it forms the best documentary evidence which we have of the connection of the inventor with the Devonshire family. Smiles, in his account of Thomas Savery,[7] gives this letter and other information. He states definitely that Thomas was the son of Richard Savery, and that he was born at Shilston, near Modbury, about the year 1650. There is, however, no entry in the parish registers of Modbury, nor in those of the adjoining parish of Ugborough, of the baptism of a Thomas Savery between the years 1640 and 1660, although these registers contain entries connected with the Saverys of Shilston. Moreover, it seems clear from Vivian's *Visitations of Devon* that Christopher Savery had more than two sons, but there is no mention of a Richard among the number.

Smiles states, from information derived from members of the family and possibly of a traditional character, that: "he was educated to the profession of a military engineer, and in course of time duly reached the rank of Trench-master." The corps of Engineers was not, however, regarded as an essential part of the military force until the year 1787, when the officers ranked with those of the Royal Artillery. The pursuit of his profession, as well as his natural disposition, led Savery to the study of mechanics, and he became well accomplished in the physical knowledge of his time. He occupied much of his spare time in mechanical experiments, and in projecting and executing contrivances of various sorts. One of his early works was a clock, still preserved in the family, which until lately kept very good time; and when last repaired by a watchmaker of Modbury was pronounced to be a piece of very good work, of a peculiar construction, displaying much ingenuity. Smiles tells us too that we find Savery a Captain of Military Engineers

[6] The writer has to thank Maj. Edward Windeatt of Totnes for the opportunity of inspecting a transcript of this interesting history.

[7] "Lives of Boulton and Watt," 1865.

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in 1702. This statement is repeated in the *Dictionary of National Biography*, but what evidence there is in support of it does not appear.

In *English Army Lists* 1661-1714 (Ed. by Charles Dalton), it is expressly noted "there is no commission for a Captain of this name in this or any other regiment." Moreover, at this period engineers did not exist as a separate corps in the Army, so it is difficult to see how there could have been such an office as a "Captain of Engineers." The Army Lists do, however, contain some entries under the name of Savery. It will be remembered that William of Orange landed at Torbay in November, 1688; on the 9th he entered Exeter, where he remained ten days. Now, on the 12th November, 1688, and so presumably at Exeter, among other commissions signed, was one to "Capt. Savery" to be Ensign. It is in connection with this entry that the note quoted above is given. The commission was in Sir John Guise's regiment of foot, which was composed chiefly of William's followers who had come with him from Holland.

In 1692 this regiment was sent to the West Indies, but before that we find a commission dated Kensington, 24th October, 1691, for Tho. Savery to be Ensign to Captain Jos. Hussey in the Duke of Bolton's first regiment of foot, commanded by Lieutenant-Colonel Norton. A detachment of this regiment was sent to Ireland in 1691, and another to the West Indies in 1692. The Editor remarks that this Tho. Savery had left the regiment before 1697. Later on we find in a list of engineer officers in Spain, 1707-12, "Thos. Savery (Acting Engineer)." The name does not appear in the previous list for 1702-7. To this entry the Editor appends a note which indicates that he had come to the conclusion that this Thos. Savery referred to was identical with the subject of this sketch. He says: "One of the most remarkable men of his time—is said to have served in William III.'s army and to have held the post of 'trench-master.' Believed to be identical with Ensign Tho. Savery of Sir John Guise's regiment, who was afterwards appointed Ensign in the Duke of Bolton's Regiment, 24 Oct., 1691. . . . Is said to have served as a Military Engineer in Spain in 1708."

The identification is weak; it is certain that our Thomas Savery, in 1708, was the holder of an important civil appointment under the Government, and it would seem unlikely that he would relinquish this, even temporarily, to volunteer for what was after all but a minor appointment with the army in Spain; his age, too, is against such an idea, for assuming the date of birth given by Smiles to be correct, he would be 58. This difficulty as to age meets us also in reference to the commission to be Ensign; in 1688 the inventor would be 38 years of age—too old one would think to care for a commission of that rank. On the other hand, it is to be admitted that there is no evidence whatever of the existence of another Thomas Savery to whom these military appointments may be credited.

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Thomas Savery, the inventor, is referred to as Captain Savery in 1700,[8] and from that date onwards to his death he was commonly spoken of as "Captain" Savery, but so far as the writer is aware he is not so designated in any official document, with the exception of the Petition Entry Book (State Papers, Domestic), where the entry of his petition in 1710, for a patent for making ovens, has a marginal note "Capt. Savery." There has been considerable discussion as to whether the title was of military, marine, or mining origin. The military description has been considered above, and Savery himself, although he wrote a book bearing the title *Navigation Improv'd*, disclaims, in *The Miners Friend*, any knowledge of shipping: "I believe it (the fire-engine) may be made very useful to ships, but I dare not meddle with that matter; and leave it to the judgment of those who are the best judges of maritime affairs."

There remains the mining connection. In Cornwall, mine managers were and are styled "Captain." It is quite possible that Savery spent the earlier years of his manhood at a Cornish mine and attained the position of captain. Coming of a family with strong Puritan leanings, it is not unlikely that the young mining captain should proceed to Exeter to meet the Prince of Orange with the object of joining his ranks as a volunteer. Being of a gentle family, he would be given a commission, but, having no military knowledge, it would be of the lowest rank. Then, the revolution accomplished, he would fall back into civil life to pursue his favourite mechanical pursuits.

However, to leave the region of speculation and come down to solid facts, we find that Savery's petition of 1694 resulted in the grant of a patent in 1696 for "his new invention, consisting of mill worke to grind and polish looking glasse, and coach glasse plates, and marble stones, and also for rowing of ships, with greater ease and expedition than has hitherto bin done by any other." In regard to the apparatus for grinding and polishing glass no definite information has come down to us, but in *The Post Boy* for 2-4 Feb., 1699, there is an advertisement which reads:—

> "The engin for grinding, pollishing, and cutting looking-glass plates, for which a patent is granted by his Majesty, is now brought to perfection; by which glass is truly ground and pollished with the best black pollish, and also the borders cut most curiously hollow, and with a better lustre than any heretofore done."

As Savery's was the only patent for polishing glass granted by William III., it is fair to assume that the invention had been taken up in practice.

This was not the case with the invention for propelling ships, of which the

[8] [W. Shiers.] "A familiar discourse or dialogue concerning the mine-adventure," London, 1700. "The making use of Capt. Savery's fire-engine, which I take to be a very ingenious invention, and deserves all due encouragement."

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inventor published a description in 1698 under the title: *Navigation Improv'd: or, the Art of Rowing ships of all rates, in calms, with a more easy, swift, and steady motion, than oars can. Also, a description of the Engine that performs it; and the Author's answer to all Mr. Dummer's objections that have been made against it.* The invention consisted of a pair of paddle-wheels worked by men turning a capstan; it was tried on a small vessel on the Thames in 1697. Mr. Dummer was the Surveyor of the Navy, who had made a report unfavourable to the invention.

In *Navigation Improv'd* Savery mentions two other inventions which he had made, but there is no information extant in reference to them beyond his own account:—

> "I have, besides the *Engine* before-mentioned, made several useful Discoveries; of which I will give some account, it not being altogether out of place; which is a method whereby I will fight any Ship, using Charge and Discharge as often as six or eight do now, and to as much purpose, without any manner of incommodation more than by the common way: so that one half of the men need not be exposed that now are, and the rest may be kept as a reserve for boarding &c., the benefit of this I leave to the ingenious Sailor; besides which I have invented a Gin of 14 inches square, portable by one man, by which one may lift the largest Cannon or Mortar into her Carriadge. But I will never discover one title of either of these, till I find justice done me on account of my Rowing Engine, I mean that it is put in Practice, and I am Rewarded; or else, that it is proved useless by an Argument, or Experiment; not by such Objections as Mr. D——— who talks of the weights of Ships in the Sea lying on this Clockwork; by which I believe, neither he himself, nor any one else, knows what he means."

While he was pressing forward the merits of his rowing engine, Savery must have been busily engaged with his great invention—the fire-engine—for raising water by fire. The patent for this invention was granted in July, 1698, and Savery had before that date exhibited a working model to the King at Hampton Court. In May, 1699, the Royal Assent was given to an Act of Parliament, by which the fourteen years protection afforded by the patent was extended by twenty-one years. In June of the same year he exhibited a model at work to the Royal Society at Gresham College, and then in 1701 he was writing *The Miners Friend*, giving a description of his invention and an exposition of its advantages. The book was issued in 1702, and in the same year it was announced in the public journals that he had set up a workshop for the manufacture of his engines and that he was ready to supply them to proprietors of mines and collieries.

A few of the engines appear to have been made, but they met with no success, and for the next three years we hear nothing more about Savery. The construction of his engine and the probable reasons of its want of success will be discussed later on. It may be interesting though to point out here that Savery in *The*

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Miners Friend suggests the use of a water cistern at the top of a house, a pipe descending from it having branches with cocks on each landing and leather pipes to connect with the cocks for use in extinguishing fires.

In 1705 Savery was appointed Treasurer for Sick and Wounded Seamen,[9] a post which he continued to hold until 1714. It is not known whether this was a lucrative appointment or not, but in the Treasury Papers for 1704 there is a complaint from the Commissioners of Sick and Wounded, that in six and a half years they had received but one and a half year's pay. Possibly the Treasurer may have been in a position to ensure the payment of his own salary, whatever that may have been. It is stated that Savery owed the appointment to Prince George of Denmark, the husband of Queen Anne, who was Lord High Admiral at the time. It was to this Prince that Savery dedicated a book which he published in the same year (1705), a translation of a Dutch Military work, *Koehoorn's Treatise on Fortification.*[10]

Whether Savery himself was acquainted with the Dutch language, and, if so, how and where he had acquired his knowledge of it, is not clear, but the translator's preface seems to suggest that he had done the work personally: "As for the translation I have endeavoured everywhere to keep exactly to the great author's sense, and generally to his words and manner of expression, where I could make it tolerably conform to our language. And therefore if the reader find here and there some periods too long, and others not so clear as he could wish them, I beg him to excuse the translator, who tho' he may be of the same opinion himself, yet would not presume to change the author's stile and manner of writing, for one more agreeable to ours; lest by so doing he should have broke in upon or mistaken his sense too."

The diffidence here expressed in regard to mistaking the sense of the original is suggestive in relation to the idea that Savery had been trained as a military engineer. One does not gather that diffidence was one of the inventor's characteristics, and had he had a training of the kind in question he would have had little difficulty in grasping the sense of the Dutch writer.

This year, 1705, was a busy year with Savery. Although there is no evidence that anything was being done in this country in the matter of the fire-engine, he was "in treaty with Baron Shutts, ye Hannover Minister, about going to Hannover to his master, to instruct his workmen in ye making and working of ye same engines." He exhibited his model at work to the young Prince of Hesse

[9] In connection with this appointment there is in the "Treasury Papers," Vol. XCV. (No. 13) a certificate that Thomas Savery, Esq., Treasurer for Sick and Wounded Seamen, and his securities, John Higgons and Elias Rich, Esqrs., and Mr. Thomas Gibbons, had executed their bonds for the performance of his office.

[10] "The new method of fortification," translated from the original Dutch, of the late famous engineer, Minno Baron of Koehoorn. By Tho. Savery, Gent. 1705.

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Cassel, who " would have had me gone home with him to Hess Cassel "; and in the following year the model of an engine for raising water by fire, which had been made under the directions of the Prince of Hesse Cassel, was referred to him to point out why it would not work.[11]

Savery was elected a Fellow of the Royal Society in 1706, and towards the end of that year we find him praying for a patent for his invention of " a new way of making double hand-bellows, which by the power of springs and screws providing a continual blast, notwithstanding the suction, by which any sort of metal may be melted in a common wood or coal fire, and will be very useful for making and raising fires in all private families, and also to all persons working in metal and ore, in as much as any ore may be melted down with its proper flux by the help of these bellows in a common chimney, without being at the accustomary charges of making essay furnaces." A patent for this invention was granted in due course. The same result did not attend a petition which he made in 1707 for a patent for " a contrivance long since made by him of a new sort of mills, to perform all sorts of mill-work on vessels floating on the water, fit to be placed on most of the rivers of this kingdom without interrupting the navigation of any of them, which invention the petitioner hopes to render of great advantage to the woolen manufacturers by many good fulling-mills, and many other useful works to be performed by mills. He is desirous to build such machines on the Thames, Trent, Savern and Mersey, and to pay an annual acknowledgment to the Crown for each one so erected."

The notes of the writer show a gap from 1707 to 1710 in the available material which has distinct reference to the inventor and this would be compatible with an absence abroad which has been discussed *supra*. At any rate, the two inventions that we have next to record seem to suggest that Savery had had his attention drawn to the requirements of an army in the field, and that he had made a sea voyage.

The last of the series of applications for patents made by Savery is in the year 1710. His petition sets forth that " he has contrived a new sort of oven for baking by the help of sea-coal, or any other fuel, though never so foul, and yet the oven shall bake much more sweet and clean that at present it is done with wood, which ovens may be kept hot for twelve months together, and be perpetually used, and the heat of them on all occasions increased or decreased at pleasure; which said ovens will bake all sorts of things much more certain and for much less charge than any yet in use, and will of course save a vast expense to her Majesty's Victualling Office in baking biscuit, and may be made portable

[11] " Royal Society Archives ": A letter to the Revd. John Harris, F.R.S., relating to a pretended invention of Dr. Papin, F.R.S. By Thomas Savery, Esquire, F.R.S. Read May 18, 1709.

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and extraordinary convenient for the army." There is no evidence that a patent was granted.

Another of Savery's inventions is referred to in a report by Sir Isaac Newton, dated January 27, 1716, which he made to the Admiralty in respect of the invention of De Saumarez for measuring a ship's way at sea. De Saumarez had petitioned the King for encouragement of his invention, the petition was referred to the Lords of the Admiralty who requested Newton to report on the practicability of the invention. In the course of his report Newton remarks: "Mr. Savery who invented the raising of water by fire, told me, about six years ago, that he had invented an instrument to measure the distance sailed, and, by his description, that instrument was much like this, (i.e. the instrument under consideration) the sea water driving round the lowest and swiftest wheel thereof, and that wheel driving round other wheels, the highest and lowest of which turned about an index to show the length of the way sailed; but I have been since credibly informed, that a sea captain, who tried that instrument, found it less exact than the logg-line."[12]

De Saumarez gives an account of Savery's invention which he had received "from a Sea Captain, called Captain Bennet, who had made an experience of it at sea, which your petitioner did immediately after set down in writing, least he should forget it, viz:—' That it was towed some time by the side of the ship, and some time by the stern, that it had an index covered with glass to shew the distance sailed, that when it was fair weather, and bore before the wind it shewed in a manner the distance sailed, which was performed by halling on board to view the index, and reputting it off again from the side of the ship into the sea with great care and precaution, least it should be bruised, which proved cumbersome and troublesome to the sea men, and of no dependence to be made upon, much less when the ship did wear and tack about, or kept to the windward, and that it was useless in the storm or rough sea; and that at the said Captain Bennet's coming home, he delivered the instrument to the said Mr. Savery telling him, that no body had had any view thereof, or opened the same to know the contrivance of it."

We may bring this account of his inventions to a close by remarking that he was the most prolific inventor of his day. In 1714 Savery was appointed Surveyor of the Water Works at Hampton Court. In a letter[13] addressed to Queen Anne, he proposes to erect in Bushey Park a set of pumps to be worked by a water wheel for the purpose of supplying the fountains at Hampton Court. The charge is to

[12] An account of the proceedings of Henry De Saumarez of the Island of Guernsey, Gent., concerning his discovery of an invention by which the course of a ship at sea may be better ascertained than by the Logg-line, viz., by a Dial placed in some convenient place of the ship, with a little bell striking from time to time, the geometrical paces, miles, and leagues, which the ship hath run. 1717.

[13] British Museum: Add. MSS. No. 20101 f. 71.

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be one thousand pounds, and Savery undertakes for a payment of two hundred and fifty pounds per annum to keep the machinery in order and to provide attendants. This letter is undated, but it must be earlier than his appointment as surveyor; very possibly it led up to that appointment.

From the obituary notices it appears that Savery held this appointment at his death, which took place in May, 1715,[14] but had given up the office of Treasurer for Sick and Wounded Seamen. His will is dated 15th May, 1715, and it was proved on the 19th of the same month by his widow, Martha Savery, the executrix and sole legatee. Savery describes himself in that document as of the parish of St. Margarets, Westminster, Esquire. His name does not occur in the registers of St. Margarets, and it is not known where he was buried.

The witnesses to the Will are Catharine Alexander, Mrs. Savery's sister, Walter Davis, probably a brother, or a brother-in-law, and John Meres, who later on figures as the leading man on the Committee of the Proprietors of the Invention for Raising Water by Fire. Savery's patent was in all probability transferred to this Company immediately after his death, for the Will expressly mentions "all my estate, termes, and interest of and in any invention or inventions by virtue of any letters patents under the Great Seal, or by Act of Parliament, or otherwise howsoever," and the Committee was certainly in existence in 1716. We have no information as to the terms upon which the patent was transferred to this Committee, but Mrs. Savery appears to have been paid, in part at any rate, by an annuity. This appears from the will of John Meres, who died in 1726, wherein mention is made of an annuity payable to Mrs. Savery from the proceeds of certain messuages in Paternoster Row.

Mrs. Savery survived her husband for a very considerable time. She died at Old Palace Yard, Westminster, in April, 1759, at the age of 104.[15] By her Will, dated 2 February, 1755, she gave to her nephew, Mr. Manwaring Davis, 1s.; and to her niece, Mrs. Elizabeth Jones, 1s.; she appoints as residuary legatee and executrix her sister Katherine Alexander, widow. Mrs. Alexander, however, died before Mrs. Savery, and the Will was proved by Elizabeth Clephan, formerly Windemude, wife of Adam Clephan, the niece of the deceased.

Dr. Rigaud,[16] following the manuscript account by John Savery, previously referred to, states that Savery is understood to have accumulated a considerable fortune, that his wife did not live to take possession of his property, and that "much of it is supposed to remain, even at this time, unappropriated." We have

[14] Captain Thomas Savery, formerly Treasurer of the Office for Sick and Wounded; and was just before his death appointed Surveyor of the Water Works at Hampton Court. "Political State of Great Britain," by A. Boyer and others, Vol. 9, p. 439. See also Le Neve's "Monumenta Anglicana," 1719, p. 306.

[15] "The Gentleman's Magazine," 1759, p. 194.

[16] Proceedings Ashmolean Society, Oxford, 1839.

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seen that the idea that Mrs. Savery died soon after her husband is incorrect. It is likely that the other belief, that he had accumulated a considerable fortune, is also without foundation.

The Treasury appears to have supplied a sum, or sums, of money for the purposes of the Commissioners of Sick and Wounded which was invested in various stocks in the names of Charles Caesar, Treasurer of the Navy (1710-1714) and of Thomas Savery, as Treasurer of the Commissioners of the Sick and Wounded.[17] No steps were taken to transfer these stocks when, in 1714, Caesar and Savery relinquished the offices in virtue of which they were the nominal holders, and the stock appears to have stood in their names until 1796, when Letters of Administration of the Wills of Caesar and Savery were granted to Thomas Ladds. The letter annexed to Savery's Will is in respect of the goods, chattels, and credits left unadministered, and Ladds is named as the administrator of the goods unadministered of Charles Caesar deceased, whilst living, a creditor of the said Savery—all persons in general having been first duly cited, with the usual intimation, but no one appearing.

There is no known authentic portrait of Thomas Savery. An engraving which purports to be a portrait is given in Smiles's *Lives of Boulton and Watt;* it is not stated from what original it was taken, but there appears to be little doubt that it was copied from a portrait given in the 1827 reprint of Savery's *Miners Friend* and in Stuart's *Anecdotes of Steam Engines*, 1829, and we have here a good instance of how difficult it is to correct an error once it has found its way into type. The reprint was issued by Robert Stuart Meikleham, who, under the pseudonym of Robert Stuart, wrote the *Anecdotes*, also *A Descriptive History of the Steam Engine*, 1824, and other works. In a letter in *The Civil Engineer and Architects Journal*, 1839 (vol. ii., p. 137), over the signature of Robert Stuart, Meikleham expressly states that the inscription of Savery's name under this portrait was a mistake, and that the engraving was inserted in the book in error. "Some of the copies (of the reprint) had a portrait designated as that of Savery. This, however, is a misnomer, occasioned by the letter-engraver affixing the name to the wrong portrait; and the mistake was not discovered till it was too late to rectify it." The letter proceeds to say that "Mr. Meikleham had an original portrait of the Captain, which he procured in 1816 from a Mrs. Boughton, of Boughton, who was connected with Savery by marriage. At that time she was very aged, and having outlived some benevolent relations she had fallen into great

[17] 1738-9. Feb. 20. Statement dated South Sea House and certified to the Treasury by J. Gyles, in pursuance of John Scrope's letter of 1738-9, January 24, of South Sea Stock, Old South Sea Annuities and New South Sea Annuities, in the names of Charles Cæsar, Esq., late Treasurer of the Navy, and Thomas Savery, Esq., deceased, late Treasurer of Sick and Wounded; and of the amount of dividends, interests and annihilations not received. "Calendar of Treasury Books and Papers," 1739-1741, p. 11.

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poverty. Mrs. Boughton knew nothing of Savery's history; she remembered her father-in-law speaking of him as having had the reputation of being a very self-willed and passionate man; very niggardly and selfish; and that he had been Sheriff of Devon. This, however, was a palpable mistake. The portrait in her possession had been painted with considerable freedom, and when Savery might have been between thirty and forty years of age. Although much mutilated, the face was perfect; so was the upper part of the peruke, and a part of the cravat. It had not been preserved from a feeling of its value, but for its convenience as a piece of furniture. The effigy had served as a chimney board. On cleaning it, there was found written on the canvas frame 'Mr. Savery, ingineer.' It had certainly at one time been in some inventory, perhaps in a sheriff's. An engraving was made from this portrait for my compilation, but, the artist not having made a passable transcript, his copy was cancelled."

It is not known what became of this portrait; the compilation referred to is no doubt the *Anecdotes of Steam Engines.*

SAVERY'S 'FIRE ENGINE.'

How and when Savery's attention was first directed to the subject of raising water by fire has not been determined. Desaguliers[18] makes a statement, now generally discredited, that:—"Captain Savery, having read the Marquis of Worcester's book, was the first who put in practice the raising of water by fire, which he proposed for the drainage of mines. His engine is described in Harris's Lexicon (*see* the word Engine), which being compared with the Marquis of Worcester's description, will easily appear to have been taken from him; tho' Captain Savery denied it, and the better to conceal the matter, bought up all the Marquis of Worcester's books that he could purchase in Paternoster-Row, and elsewhere, and burn'd 'em in the presence of the gentleman, his friend, who told me this."

Desaguliers proceeds to give what he alleges to be Savery's own explanation of the manner in which his invention originated: He said that he found out the power of steam by chance, and invented the following story to persuade people to believe it, viz. that having drank a flask of Florence at a tavern, and thrown the empty flask upon the fire, he call'd for a bason of water to wash his hands, and perceiving that the little wine left in the flask had filled up the flask with steam, he took the flask by the neck, and plunged the mouth of it under the surface of the water in the bason, and the water in the bason was immediately driven up into the flask by the pressure of the air." Desaguliers, however, contends that such an experiment was impossible, he had tried it himself and failed to obtain the result alleged.

[18] J. T. Desaguliers: "A Course of Experimental Philosophy," 1744, Vol. II., p. 465.

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We must, however, acquit Desaguliers of the responsibility of being the first to give currency to these stories; they had appeared many years before the date of his book in an enigma in *The Ladies' Diary* for 1725. *The Ladies' Diary* was an annual publication of a class much in favour at that time, combining an almanac with a variety of other more or less useful matter; its characteristic feature was mathematical problems. Its editor at this date and for many years after was Henry Beighton, of Griff, in Warwickshire. Beighton had been concerned in the erection of some of the early Newcomen engines; he was personally acquainted with Desaguliers, and, no doubt, with Savery also. The enigma does not take rank as poetry, but it is curious and, therefore, no excuse is needed for reproducing it.

THE PRIZE ÆNIGMA.

I sprung like Pallas, from a fruitful Brain,
About the time of Charles the Second's reign.
My father had a num'rous progeny,
And therefore took but little care of me:
An hundred children issu'd from his Pate;
The number of my birth was Sixty eight.
My body scarcely fram'd, he form'd my soul,
Such as might please the wise, but not the dull:
Yet sundry pictures of my face he drew;
As of many other of his children too:
These Pictures lay, whilst none my worth did know,
In Paul's Church-yard and Pater-noster Row.
My father dead, my self but few did see,
Until a warlike man adopted me;
Destroy'd what Records might disclose my birth,
Said he begot me, and proclaim'd my worth.
Begetting me he call'd a chance—a Task
    Easie to him, assisted by a Flask.
    He then to me strange education gave,
Scorch'd me with heat, and cool'd me with a Wave:
More work expected from my single force,
Than ever was perform'd by Man or Horse.
To mend my shape, he oft deform'd it more;
Which sometimes made me burst, and fret, and roar;
Then from my eyes, such vapours issu'd forth
As Comets yield, or Twilights of the north:
And like those Lights the Vulgar I surprize;
Not those that know my nature, or the wise.

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My heart has ventricles, and twice three valves;
Tho' but one ventricle, when made by Halves.
My *Vena Cava*, from my further ends
Sucks in, what upward my great Artery sends.
The Ventricles receive my pallid blood,
Alternate, and alternate yield the Flood:

By Vulcan's Art my ample Belly's made;
My Belly gives the Chyle with which I'm fed;
From Neptune brought, prepar'd by Vulcan's aid.

My father (I mean he who claim'd my birth)
My dwelling fix'd in the Caverns of the earth;
And there he said, I shou'd in strength excel;
But there, alas; I was but seldom well.
Torrents he bad me stop:—I wanted breath;
And Nature strain'd too much, will hasten death.
In this sad state, to languish I begin,
Until a Doctor sage, new coming in,
Condemn'd the methods that were us'd before;
And said,—That I in caves shou'd dwell no more:
Then I shou'd dwell in free and open Air,
And gain new vigour from the atmosphere:
An house for me he built—Did orders give,
I shou'd no weight above my strength receive;
And that I shou'd, for breath, and health to guard,
Look out of windows when I labour'd hard.
These gentle means my shape have alter'd quite;
I'm now increas'd in strength, and bulk, and height;
I now can raise my hand above my head;
And now, at last, I by my self am fed.

On mighty arms, alternately I bear
Prodigious weights of water and of air;
And yet you'll stop my motion with a hair.

He that can find me shou'd rewarded be,
By having, from my Masters, Liberty,
Whene'er he pleases, to make use of me.

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In the volume of the *Diary* for the following year is given an explanatory note, as follows:—

"The Prize Ænigma is a description of the invention and progress of the Engine for raising water out of Mines by the force of fire. It was first used by Herbert, Marquis of Worcester, about the year 1644, and published in his *Century of Inventions* anno 1661. In 1689 Capt. Tho. Savery got a patent for 14 years, and an Act of Parliament for 21 years longer for that Invention. In the year 1712 Mr. Newcomen, by applying the weight of the Atmosphere instead of the Elasticity of the steam, brought it to the perfection wherewith it is now used."

The Marquis of Worcester obtained an Act of Parliament in 1663 entitling him to receive the benefit and profit of a "water commanding engine" which he had invented; his *Century of Inventions* was published in the same year. No. 68 of the *Century* is "An admirable and most forcible way to drive up water by fire," etc. It is difficult to form any clear idea of what the Marquis had in view, but apparently he contemplated forcing water by steam pressure, but not the combined sucking and forcing action which characterized Savery's fire-engine. What truth there may be in the story that Savery had destroyed all the copies of the Marquis's book that he could obtain, we have now no means of ascertaining. The story was not published during Savery's lifetime.

The ventricle of the enigma is what we have referred to above as the receiver, the vena cava indicates the suction pipe, the artery the force pipe, the blood the water, and the chyle the steam. The reference to the engine being fixed in the caverns of the earth will be understood when it is borne in mind that it had to be placed within from twenty to thirty feet of the surface of the water. "New coming in" applied to the "Doctor Sage" is, of course, a pun upon "Newcomen."

Another account is given by Switzer:[19] "The first hint from which it is said he took this Engine, was from a tobacco pipe, which he immers'd to wash or cool it, as is sometimes done; he discover'd by the rarefaction of the air in the tube by the heat or steam of the water, and the gravitation or impulse of the exterior air, that the water was made to spring thro' the tube of the pipe in a wonderful surprising manner."

To come to facts which are beyond dispute, we find that in July, 1698, Thomas Savery, gentleman, obtained the grant of a patent for "A new invention for raiseing of water and occasioning motion to all sorts of mill work by the impellent force of fire, which will be of great use and advantage for drayning mines, serveing townes with water, and for the working of all sorts of mills where they have not the benefitt of water nor constant windes."

The protection accorded by this grant was for the term of fourteen years. In

[19] S. Switzer: "Hydrostaticks and Hydraulicks," 1729, Vol. II., p. 325.

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the following year, 1699, an Act of Parliament was passed which extended his protection by the term of twenty-one years. The Act, after reciting the terms of the grant of patent continues: "And whereas the said Thomas Savery hath, by his great care, paines, and expence since the granting of the said Letters Patent, greatly improved the said invention, which is likely to be of great use and advantage to His Majesty's subjects in general, but may and probably will require many yeares' time and much greater expence than hitherto hath been to bring the same to full perfection, and the said Thomas Savery thereby deserves a better encouragement by having a longer terme of yeares allowed him for the sole use and benefitt of the said invention."

In 1701 the invention was protected in Scotland by an Act of Parliament granting to Mr. James Smith, of Whitehill, the sole right to use in Scotland Savery's invention of "an engyne or invention for raiseing of water and occasioning motion of mill-work by the force of fire." The Act was passed upon the recommendation of a committee which reported upon a petition by James Smith, setting forth that Savery had obtained in England his Majesty's Letters Patent under the Great Seal and likewise an Act of Parliament for the sole use of his invention for the space of thirty-five years, "and that by Articles of Agreement signed betwixt the said Captain Thomas Savery and the petitioner . . . he hath allowed and given to the petitioner the communication of the said invention with the model of the said engine to be made use of by him within this Kingdom upon the conditions and provisions contained in the said articles." The protection is to terminate with that granted in England.

Savery had previously exhibited a model of his invention to the King at Hampton Court, and in 1699 he exhibited it in public for the first time. In the *Philosophical Transactions* (Vol. 21, p. 228) is an entry "Mr. Savery, June 14, 1699. Entertained the Royal Society with shewing a small model of his engine for raising water by the help of fire, which he set to work before them, the experiment succeeded according to expectation, and to their satisfaction." Following this note is a description, and drawing of the apparatus, to which we shall return later on.

The practice of requiring patentees to file specifications did not prevail in Savery's time. He, however, gave what amounts to a specification when, in 1702, he published: *The Miners Friend; or, an engine to raise water by fire, described, and of the manner of fixing it in mines, with an account of the several other uses it is applicable unto; and an answer to the objections made against it,* by Tho. Savery, Gent., London, 1702. This work contains three dedications, the first to the King, the second to the Royal Society, and the third "To the Gentlemen Adventurers in the Mines of England." In the first, Savery states that the invention is now fully completed and put in practice in the King's dominions with

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repeated success and applause. In the second he says: "I have met with great difficulties and expense, to instruct handicraft artificers to forme my engine according to my design; but my workmen, after so much experience, are become such masters of the thing, that they oblige themselves to deliver what engines they make me, exactly tight and fit for service, and as such I dare warrant them to any body that has occasion for them."

Savery had indeed by this time set up a factory for the production of his engines, as appears from this announcement in the *Post Man*, March 19-21, 1702: "Captain Savery's Engines which raise Water by force of Fire in any reasonable quantities and to any height, being now brought to perfection, and ready for Public use. These are to give notice to all Proprietors of Mines and Collieries which are incumbred with water, that they may be furnished with Engines to drain the same, at his Workhouse in Salisbury Court, London, against the Old Playhouse, where it may be seen working on Wednesdays and Saturdays in every week from 3 to 6 in the afternoon, where they may be satisfied of the performance thereof, with less expense than any other force of Horse or Hands, and less subject to repair."

It is interesting to note that this, the first, factory for the production of steam engines goes back to the year 1702. It is not known how long Savery continued to work it. Salisbury Court extended from Fleet Street towards the river, near St. Bride's Church. The playhouse was Dorset Gardens Theatre, one face of which was towards the river.

The first engines, however, were not constructed at Salisbury Court; Switzer (1729) relates: "I have heard him (Savery) say myself, that the very first time he play'd, it was in a potter's house at Lambeth, where though it was a small engine, yet it forc'd its way thro' the roof and struck up the tiles in a manner that surpris'd all spectators."

In the third dedication of *The Miners Friend*, to the gentleman adventurers in the mines of England, Savery states: "And though my thoughts have been long imployed about water-works, I should never have pretended to any invention of that kind, had I not happily found out this new, but yet a much stronger and cheaper force or cause of motion that any before made use of. But finding this of rarefaction by fire, the consideration of the difficulties the miners and colliers labour under by the frequent disorders, cumbersomeness, and in general of water engines, incouraged me to invent engines to work by this new force, that tho' I was obliged to incounter the oddest and almost insuperable difficulties, I spared neither time, pains, nor money till I had absolutely conquered them."

Dr. Harris in his *Lexicon Technicum*, 1704, reproduces the drawing and description of the engine from *The Miners Friend*, and remarks of the inventor, "he

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hath shewed as great ingenuity, depth of thought and true mechanical skill, as ever discovered itself in any design of this nature."

The engine of *The Miners Friend* differs in some respects from that shown in the *Philosophical Transactions*; it attempts a more complete solution of the problem. It will be convenient to point out these differences after a consideration of the Savery engine in its simplest form as erected in 1711 or 1712 at Campden House, Kensington. We have a full description and drawing of this engine in Bradley's *New Improvements of Planting and Gardening*, 1718. Bradley says: "It is now about six years since Mr. Savery set up one of them for that curious gentleman Mr. Balle, at Cambden House, Kensington, near London, which has succeeded so well that there has not been any want of water since it has been built." The engine is described again by Switzer in 1729, apparently as being still at work. This author refers to it as the plainest and best proportioned of any he had seen.

Referring to the illustration (*see* Plate XX.), the boiler B is placed above an open fire A and communicates by the pipe D with the receiver E; the receiver is mounted upon a hollow box or "engine tree" F, to which the suction pipe G and the force pipe L are connected, and these pipes have valves which open upwards at I and K. Upon opening the regulator C steam passes into the receiver, displacing the air which passes by the valve K up the force pipe. When the receiver has become charged with steam, the regulator is turned to shut off the supply, and a little cold water is dashed upon it; the steam is condensed, a vacuum is produced, and water rushes up the suction pipe by the valve I and into the receiver. The regulator is now opened, and the steam pressing upon the surface of the water in the receiver forces it up the pipe L. When the receiver has become emptied of water and charged with steam, the regulator is again closed and condensation is effected by turning the tap M of the small branch on the force pipe which in the working of the engine remains charged with water. The engine may then be kept at work, as long as the charge of water in the boiler lasts, by turning alternately the regulator C and the tap M. The pipe N serves both for charging the boiler with water and as a gauge pipe; its lower end descends nearly to the bottom of the boiler, so that if upon turning the cock at its upper end, steam escapes, not water; the boiler requires replenishing with water. The pipe was also used to let off steam when discontinuing pumping. The boiler, steam pipe and receiver were made of copper, the suction and force pipes of wood. This engine sucked from a depth of sixteen feet and forced to a height of forty-two feet, the water pipes were three inches bore and the steam pipe one inch. The receiver held thirteen gallons and the boiler three times that quantity. Bradley states: "You may rise four of the receivers full of water in one minute," i.e., 3,120 gallons per hour. The engine cost fifty pounds.

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This apparatus produced an intermittent delivery of water. The model exhibited to the Royal Society, as shown in the *Philosophical Transactions,* had two receivers working alternately, whereby a continuous delivery was obtained; the regulators were opened and closed separately and the boiler was placed above a closed furnace. No external jet of water for condensing the steam is shown, nor is there any description of its being used. Apparently, in 1699, condensation was effected by radiation assisted by the incoming water. The engine of *The Miners Friend* is a development of the two-receiver engine; the regulators of the two receivers are linked together, so that one is closed as the other is opened, and the branch pipe supplying the condensing water is arranged to swivel in such a manner that it may be turned first over one and then over the other receiver. In addition, an auxiliary boiler is employed whereby the main boiler may be replenished with water during the working of the engine; the auxiliary boiler is charged with water and its furnace set going; part of the water is converted into steam and the pressure generated forces the remaining water, or part of it, into the main boiler; the connection is then cut off, when the auxiliary boiler may be recharged. It is interesting to note that Savery himself designates the steam generators by the term still in common use—" boilers."

Savery considered that his engine could suck from a depth of 22 to 26 feet, and then force to a height of from 60 to 80 feet. When a greater lift was required, as in mines, two or more of the engines were to be used, one above the other in the pit. The inventor pointed out how his engine might be used to produce rotary motion, and to actuate mills, by allowing the water raised to fall over water-wheels; he suggested that it might be used on ships, but does not indicate that it was their propulsion that he had in view.

It would seem then that at the date of *The Miners Friend* there were distinct prospects of the success of the invention in practice. Savery writes as if several of the engines were actually at work " put in practice . . . with repeated success and applause," and, in referring to the use of the apparatus in coal mines, he states that the consumption of coal is so small as to be of no account, " as we have experienced "; and again, in connection with the action of the draught of the boiler furnace in assisting in the ventilation of the mine: " this I have tried and know to be true." Indeed, it is difficult to think that he would have ventured to set up a special workshop, unless the outlook had been encouraging. However, apart from the engine at Campden House, referred to above, and a similar engine at Sion Hill for the Duke of Chandos, we learn of no successful application. Engines were probably set up at mines in different parts of the country and after trial given up as unworkable. Dr. Wilkes, writing in the first half of the eighteenth century, mentions an engine set up in Staffordshire in the following terms: " Mr. Savery set down one of those engines in the Liberty of Wednes-

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bury, not far from Willingsworth in order to drain what was then called the Broad Water as well as to lay the mine dry which was so much wanted."[20] Shaw, in his *History of Staffordshire*,[21] gave what purported to be Dr. Wilkes's note, but as will be seen, he added to it considerably: "This gentleman (Savery) set one of these engines down about the year 17— in the liberty of Wednesbury, near a place called then the Broad waters, which is now dry land again. For this place being low ground, the water rose so hastily many years ago, and in such quantities from the Coal pit, that it covered some acres of land. . . . The Engine thus erected could not be brought to perfection, as the old pond of water was very great, and the springs very many and strong that kept up the body of it; and the steam when too strong tore it all to pieces: so that after much time, labour and expense, Mr. Savery was forced to give up the undertaking, and the engine was laid aside as useless; so that he may be said to have discovered a power sufficient to drain any kind of mine, but could not form an engine capable of working and making it useful."

Shaw's account suggests that the difficulty was to make the parts sufficiently strong. Bradley, whose favourable account of the Campden House engine has been referred to, in discussing the deficiencies of the engine erected in 1712, or soon after, at York Buildings Water Works, seems to find the working of the regulator the chief difficulty. This engine had two receivers (as in Savery's original plan, of which Bradley seems to have been unaware): "That gentleman (Savery) tho' he had before set up his engines with good success at Cambden House, near Kensington, was not content with the plainness of them, when he undertook so great a work as furnishing the publick with water, but doubled every part of the York-buildings engine, and by that made it impracticable for one man to work it; and it was liable to so many disorders, if a single mistake happen'd in the working of it, that at length it was look'd upon as a useless piece of work, and rejected."[22]

Desaguliers, who says nothing of the difficulty of working the valves, refers to the difficulty of keeping the joints tight: "I have known Captain Savery, at York-Buildings, make steam eight or ten times stronger than common air; and then its heat was so great, that it would melt common soft solder; and its strength so great as to blow several of the joints of his machine."

It will be understood that Savery's engine was not self-acting, that is to say, that the valves were opened and closed by manual labour. In regard to this, Savery, in *The Miners Friend*, assures the public that the attending and working of

[20] Copied from the Wilkes MSS. in the Salt Library at Stafford, by the kindness of the former librarian, Mr. John W. Bradley.

[21] Shaw: "The History and Antiquities of Staffordshire," 1798-1801, Vol. II., p. 85.

[22] R. Bradley: "Ten Practical Discourses concerning the Four Elements, etc.," 1733, p. 33.

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the engine is so far from being difficult or intricate, "that it is familiar and easie to be learned by those of the meanest capacity, in a very little time; insomuch that I have boys of 13 or 14 years of age, who now attend and work it to perfection, and were taught to do so in a few days; and I have known some to learn to work the engine in half an hour." And again he says: "The labour of turning these two parts of the engine, viz., the regulator and the water-cock, and tending the fire, being no more than what a boys strength can perform for a day together." However, he admits that he would prefer men, as being more reliable than boys.

It is clear that the apparatus was not one in which steam could be employed with any degree of efficiency. The admission of high pressure steam upon the surface of a body of cold water in a vessel at the temperature of the water would necessarily result in the condensation of a considerable amount of it to no useful purpose.

But to neither of these defects can the want of success of the engine fairly be attributed. There should have been no particular difficulty in working the valves by hand, seeing that the operator could take his own time about it; the consideration of the cost of the labour involved in this operation must have been a matter of little importance in these days, and the engine, although extravagant in its consumption of steam, would perform the work more cheaply than the labour of men or animals. Savery considered that he could raise as much water for eightpence as would cost a shilling with the old appliances in coal pits—a not extravagant estimate. He did not set his engine in competition with water or wind power.

Despite all the inventor's assertions as to the skill and proficiency of his workmen, the failure of his engines must be attributed in the main to imperfect workmanship and materials. To-day there would be no difficulty in making a successful working machine to the drawings given in *The Miners Friend*, indeed in a modified form, and with an automatic steam valve, Savery's principle is embodied in the modern pulsometer. Possibly had Savery contented himself with forcing to small heights, and thereby avoided the use of high pressure steam, he would have met with greater success; he fully realised that as far as the suction effect of the apparatus was concerned nothing was gained by increase of pressure.

So recently as about the year 1820 an engine on Savery's plan was in use in an engineer's works at Kentish Town for the purpose of lifting water to turn the water-wheel by which the machinery in the shops was driven. The valves of this engine were worked from the axle of the water-wheel. The apparatus had been in successful use for a considerable number of years.

As we have seen, Savery's apparatus, while it answered its purpose well when constructed on a small scale, met with no success in the primary application which

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the inventor had in view—that of pumping in mines, and it has been stated that the apparatus erected for public water supply at York Buildings about 1712 was a failure. There is no evidence that Savery in the few remaining years of his life concerned himself with the invention in any way.

By this time, however, there had appeared upon the scene another Devonian—Thomas Newcomen—who, dealing with the problem on entirely different lines, succeeded in arriving at a satisfactory solution in the atmospheric engine, an engine in which a cylinder and piston were used to work ordinary pumps. With his invention we shall deal in the second part of this paper.

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A Holograph Letter of Faraday.

Communicated by Professor L. Darmstaedter.

This letter is preserved in the Staatsbibliothek at Berlin in the Darmstaedter Collection. The letter is dated February 2nd, 1821, from the Royal Institution; this was the year of Faraday's marriage and the year that brought him international fame owing to his discovery of the electro-magnetic rotations.

Professor J. A. Fleming, F.R.S., to whom the letter was submitted is good enough to write: "The facts as stated by Faraday are quite correct. He and Ampère had evidently corresponded on the discovery of the rotation of the pole of a magnet round a current. Ampère discovered that a magnet could be made to rotate round its own axis by passing a current along it and Faraday that a part of a circuit could be made to rotate in a magnetic field, as described. Ampère seems to have thought that it afforded a means of deciding whether the Ampèrian currents were molecular or circulated round the magnet as a whole, but Faraday evidently differed from him."

The letter is not mentioned in the important biographies of Faraday[1] nor does it appear in the life of Ampère,[2] but there is an interesting reference to the effect upon him of Faraday's researches in a letter to J. Bredin, 30 November, 1821.[3]

"En arrivant ici (i.e., L'Institut de France) la métaphysique remplissait ma tête; mais depuis que le mémoire[4] de M. Faraday a paru, je ne rêve plus que courants électriques. Ce mémoire contient des faits electro-magnétiques très singuliers qui confirment parfaitement ma théorie quoique l'auteur cherche à la combattre pour lui en substituer une de son invention."

TRANSCRIPT.

Royal Institution,
Febr. 2nd, 1821.

Sir,—

I am very much flattered by the letter you did me the honor to send me and by the present of the Exposé for which I beg leave to return you my best thanks.

Having occasion to write to M. Hachette I have presumed to accompany my

[1] Bence Jones, "Life and Letters of Faraday," 1870. J. H. Gladstone, "Michael Faraday," 1873. S. P. Thompson, "Michael Faraday, his Life and Work," 1898.

[2] Andre Marie Ampère et Jean Jacques Ampère. Correspondance et Souvenirs (de 1805 à 1864) recueillis par Madame H. C(neuvreux), 1875.

[3] "Loc. cit.," i. 206.

[4] "Quarterly Journal of Science," October, 1821.

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letter to him by this to you and venture a few observations on your beautiful experiment of the rotation of the magnet, etc., etc. I repeated the experiment the day after I received your letter and using Hare's calorimeter an instrument equivalent to a very large pair of plates instantly obtained the revolution. I found it convenient to cement a small piece of glass tube on the upper pole of the magnet which forming a cup to receive the mercury made contact very easy without the chance of touching the solid parts of the arrangement.

You mention your opinion that this experiment will be competent to decide the question whether the currents of electricity assumed by your theory exist round the axis of the magnet or round each particle from which I gather that the view you take of it differs from the one I at present have, since to me it seems a modification of the revolution of a wire round a pole. I presume much in differing from yourself on this subject and more in stating the difference to *you* but I do not hesitate a moment in concluding that in the true spirit of philosophy you are anxious to hear (or at last willing) even the doubt of one young in the subject if there be the smallest possibility that they will either correct or confirm previous views.

The rotation of the magnet seems to me to take place in consequence of the different particles of which it is composed being put into the same state by the passing current of electricity as the wire of communication between the voltaic poles, and the relative position of the magnetic pole to them. Thus the little arrows may represent the progress of the electricity; then any line of particles parallel to them except that line which passes as an axis through the pole (represented by a dot) will be in the situation of the revolving wire and will endeavour to revolve round the pole and as all the lines act in the same direction or tend to go one way round the pole the whole magnet revolves. That this is the way in which the magnet revolves is I think evident from the considerations above; from the revolution being in the same direction as with the wire and from the following analysis of the experiment I took a piece of copper wire similar in form to the magnet and having floated it upright in mercury placed a little cup on the top to contain a globule of mercury and then connected the voltaic poles just as they were with the magnet then placing the pole of a strong magnet beneath the cup containing the mercury. It when exactly in line with the axis of the wire made it rotate slowly on its own axis. In this experiment it appears to me that every thing was in the same state as in the former experiment except that the pole was removed out of the revolving mass but present in the line of the axis and the rotation of the wire on its own axis seems to me an effect produced exactly in the same manner as the rotation of the magnet on its own axis.

[5] The sketch will be found on the page of the letter reproduced on Plate XXI.

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I have been thus diffuse in giving my view of the rotation because if it be the true one I do not see how the experiment determines the position of the currents more than the one in which a wire rotates round a pole: Perhaps however you have the same view of it but see explanation I do not. I regret that my deficiency in mathematical knowledge makes me dull in comprehending these subjects. I am naturally sceptical in the matter of theories and therefore you must not be angry with me for not admitting the one you have advanced immediately. The ingenuity and applications are astonishing and exact. But I cannot comprehend how the currents are produced and particularly if they be supposed to exist round each atom or particle and I wait for further proofs of their existence before I finally admit them. Permit me to express my respect for your high philosophical character and to apologise for thus intruding on your time.

I am, Sir,

Your obliged and Humble Servant,

M. FARADAY.

M. Ampère.

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Analytical Bibliography of the History of Engineering and Applied Science 1920-1924.

Part II.

The "Beiträge zur Geschichte der Technik" is here again abbreviated to B.G.T. I have to acknowledge with thanks the co-operation of Mr. A. A. Gomme in the preparation of this List. Notes of articles of historical interest from 1900 to date, not already included, will be welcomed.—E.W.H.

Aeronautics—*See* Aeroplanes; Flight: *Gliding*.

Aeroplanes—The Langley flying machine. —*Nature*, 3 Nov., 1921, pp. 297-8.

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——— Roaring Meg [mortar used in the Civil Wars]. By A. Watkins.—*Trans. Woolhope Nat. Hist. Field Club*, 1918-20-(1921), pp. 172-4. 1 pl.

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——— Ueber den derzeitigen Stand unserer Kenntnisse von den Anfängen der Pulverwaffen. By Johann Ottsen. —*B.G.T.*, Vol. 13, 1923, pp. 1-9. 3 figs.

See also Firearms; Iron Manufacture; Targets; *also* Bodmer (J. G.).

Artillery: Breechloading—Nochmals die älterer Hinterladungs-geschütze. By P. Reimer.—*Zeits. f. Hist. Waffenkunde*, 1922, pp. 194-9. 4 figs.

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Chocolate—Geschichte der Schokolade und der Schokolade-industrie. By Hugo Th. Horwitz.—*B.G.T.*, Vol. 13, 1923, pp. 125-145. 16 figs.

Churn—[Reference in *Agricultural Ledger*, July, 1895, to a proposed history of the churn].—*Nature*, 7 July, 1921, p. 587.

Classical Science—1, Mathematics and Astronomy. By Sir T. L. Heath; 2, Natural Science. By D'Arcy W. Thompson; 3, Biology and Medicine. By Chas. Singer. — *R. W. Livingstone's* The Legacy of Greece, 1921, pp. 97-248.

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Clocks and Watches — History of the marine chronometer. By R. T. Gould.—*Geogr. Jl.*, April, 1921, pp. 253-70. 6 figs.

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See also MECHANISM.

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Report of The Council for the Session 1922-23.

Presented at The Annual General Meeting December 6th, 1923.

The Council has pleasure in presenting this the Third Annual Report upon the work of the Society, with the accompanying Statement of Accounts, and it does so with the conviction that the past Session has been a success and that the standing of the Society is improving.

The period has been one of slow but steady progress. No changes in the constitution of the Society nor in its procedure have been found necessary. The attendance at meetings has been kept up and the interest of members seems unabated.

The number of new members elected has been 28, and although this seems a small number yet it is a large one relative to the total membership. The increase in the number of libraries and institutions that have joined for the "Transactions" is 16. The Society has to deplore the loss by death of Mr. Robinson and Mr. Russell. Three members have resigned. Thus the total of members is now 148 and of the libraries, etc., is 23. It is realised that the Society cannot ever hope to be a very large one, as the appeal it makes is to a limited circle; it is reasonable, nevertheless, to look forward ultimately to a membership of twice this number as the Society becomes more widely known.

A fact worthy of note is the large number of new members from America. The result is in part the outcome of the visit that our Hon. Secretary paid early in the year to America, where through existing members he got into touch with a number of gentlemen of like tastes. A movement is on foot to establish an affiliated body there to tap more effectually people in the Western hemisphere interested in the history of technology; to this movement the Council gives its unqualified approval, as carrying out the aims of the Society.

After much deliberation the Council decided upon an emblem for the Society. This is a griffin rampant regardant with the motto "Actorum memores simul affectamus agenda."[1]

The "Transactions" of the Society for 1921-1922, Vol. II., was issued to members late in the Session. It includes, besides the papers mentioned in the last Report as having been read, a useful "Bibliography" and some "Notes and Communications," with the result that the volume is nearly twice as large as

[1] See Vol. II., p. xii., and this Vol., p. xii.

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the preceding Vol. I. It is hoped to make these features permanent, but this can only be done by co-operation on the part of members.

The Council has now decided on a standard binding for the "Transactions," and notices have been sent to all members giving them an opportunity to have their volumes so bound.

During the Session seven meetings have been held, five in London, one in Birmingham, and one, detailed at greater length below, at Rochester. The titles of papers presented, the authors' names, and dates of the meetings are:—

"Simon Goodrich and his work as an engineer," Pt. I., 1796-1805: E. A. Forward, A.R.C.S., M.I.Mech.E., Oct. 26th.

"Notes on the early history of steel-making in England": Rhys Jenkins, M.I.Mech.E., Nov. 29th.

"Notes on Old Windmills": A. Titley, M.I.Mech.E., Jan. 26th.

"East Indian Cotton Prints and Paintings of the 17th and 18th Centuries": G. P. Baker, Feb. 7th.

"The Early History of the Gas Process": David Brownlie, F.C.S., A.I.Mech., F.I.C., etc., March 20th.

"Notes on Sir George Cayley as a Pioneer of Aeronautics": J. E. Hodgson, May 23rd.

"The Preservation of Historic Buildings and Ancient Monuments": Sir Frank Baines, C.B.E., M.V.O., June 21st.

Most of these papers were reported in the Press at the time, and they will appear in the "Transactions" in due course.

It is a matter of regret to the Council that owing to the shortage of papers actually ready it was not practicable to draw up a programme for the Session beforehand. A list of suggested subjects for papers has been drawn up and is in the Secretary's hands, and it is hoped that Members will avail themselves of it and thus remedy the shortage in the future.

The meeting held on November 29th was the Annual General Meeting, and at that meeting an accession of fresh blood to the Council was made by the election of three new Members of the Council in addition to those who retired and were re-elected.

The Summer Meeting, which lasted two days, was held at Rochester on June 21st and 22nd. On the morning of the first day a visit was paid to the Fabric Printing Works of Messrs. G. P. & J. Baker, Ltd., of Crayford. In the absence of Mr. Baker, the party was conducted through the works by Mr. H. Clayton and was particularly interested in the process of block printing by hand. Chatham Dockyard was visited by kind permission of the Admiral Superintendent in the afternoon. In the evening the Members and guests dined together at the Bull Hotel, Rochester. The guests of the evening were His Worship the Mayor

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of Rochester and Admiral of the Medway, Alderman A. E. J. Price, Sir Frank Baines, C.B.E., M.V.O., Mr. G. A. Bassett of H.M. Dockyard, and Mr. Edwin Harris, the local antiquary. In the evening Sir Frank Baines gave a lecture, the title of which is set out above; this was held very appropriately in the Guildhall, by kind permission of and under the chairmanship of the Mayor. By courtesy of the Mayor the city regalia were on view at the conclusion of the lecture.

On the second day, Hayle Mill, of Messrs. J. Barcham Green & Son, Tovil, near Maidstone, was first visited under the guidance of Mr. Herbert Green, his son and the works manager. Here the manufacture of hand-made paper with scrupulous attention to quality was seen. At the close of the visit Mr. Green presented each member of the party with samples of the products that had been inspected. Later, the Great Ivy Mill, higher up the valley, was visited under the guidance of Mr. Hilder A. Bowers, the Manager; here the manufacture of millboard in all its stages was shown.

After lunch a quick run brought the party to Rochester, where the afternoon was spent in visits to the Cathedral and the Castle, Mr. Harris kindly acting as guide. The meeting was pronounced by those participating a great success. Notices appeared in the local Press.

Quite a number of requests for information on historical matters connected with engineering or industry have been received both from Members and others and have been satisfactorily dealt with. In some cases they have led to applications for membership.

During the year several Members have been kind enough to offer to the Society gifts of books, pamphlets, or drawings. At present there is neither accommodation nor staff to deal with such objects, and the Council has regretfully decided that it cannot accumulate property. The Secretary will, however, always be prepared to pass on to a Member who is known to be interested, any such matter offered.

The financial position of the Society is sound, as will be observed by a glance at the Treasurer's Statement of Account attached. It is a matter for some regret, however, that the disposable balance is not sufficiently large as to warrant the Council in embarking upon, as they would like to do, some extra publication, such as the reproduction of a MS., the reprint of an important old book, or the translation of a foreign work. Perhaps some Member will take up this matter.

LOUGH. PENDRED.

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NEWCOMEN SOCIETY.

Revenue Account from 1st. October, 1922 to 30th September, 1923.

Dr.

Expenditure.	£	s.	d.	£	s.	d.
To Hire of Rooms and Expenses of Ordinary and Summer Meetings	28	18	7			
Printing and Stationery, including preparation of and Printing "Transactions," Vol. II.	128	2	1½			
Typing and Mimeographing	17	4	4½			
Postages, telegrams, parcels, stamps and travelling expenses	12	19	4½			
Bank Charges and Commission	0	4	8			
				187	9	1½
Excess of Income over Expenditure for the Year				28	10	5½
				£215	19	7

Cr.

Income.	£	s.	d.	£	s.	d.
By Subscriptions and Donations for the Year	144	3	9			
Members' and Visitors' Contributions to the Summer Meeting	20	17	6			
Sale of "Transactions"	50	1	1			
Bank Interest to 30th Sept.	0	17	8			
				215	19	7
				£215	19	7

Balance Sheet as at 30th September, 1923.

Liabilities.	£	s.	d.	£	s.	d.
Balance brought forward from 1st October, 1922	86	10	1			
Surplus from Revenue Account ending 30th September, 1923	28	10	5½			
				115	0	6½
				£115	0	6½

Assets.	£	s.	d.	£	s.	d.
Cash as under:—						
On Deposit	70	0	0			
On Current Account	31	6	11			
In Treasurer's hands	13	13	7½			
Stock of "Transactions" (not valued)				—	—	—
				115	0	6½
				£115	0	6½

The above Accounts have been examined with the Books and Vouchers, and found correct.

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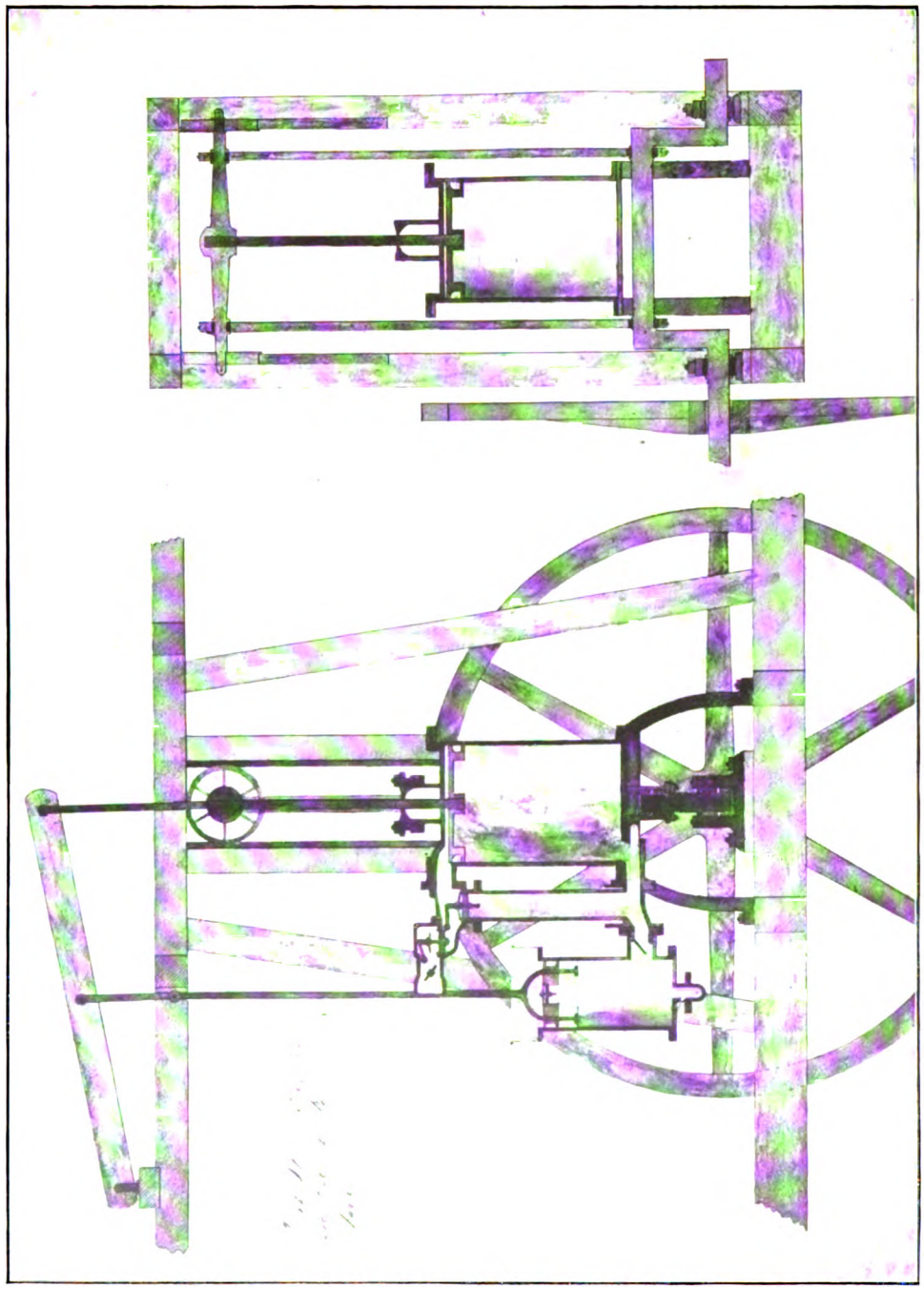

SKETCH OF SADLER'S STEAM ENGINE, 1700.
The first steam engine erected at Portsmouth Dockyard.

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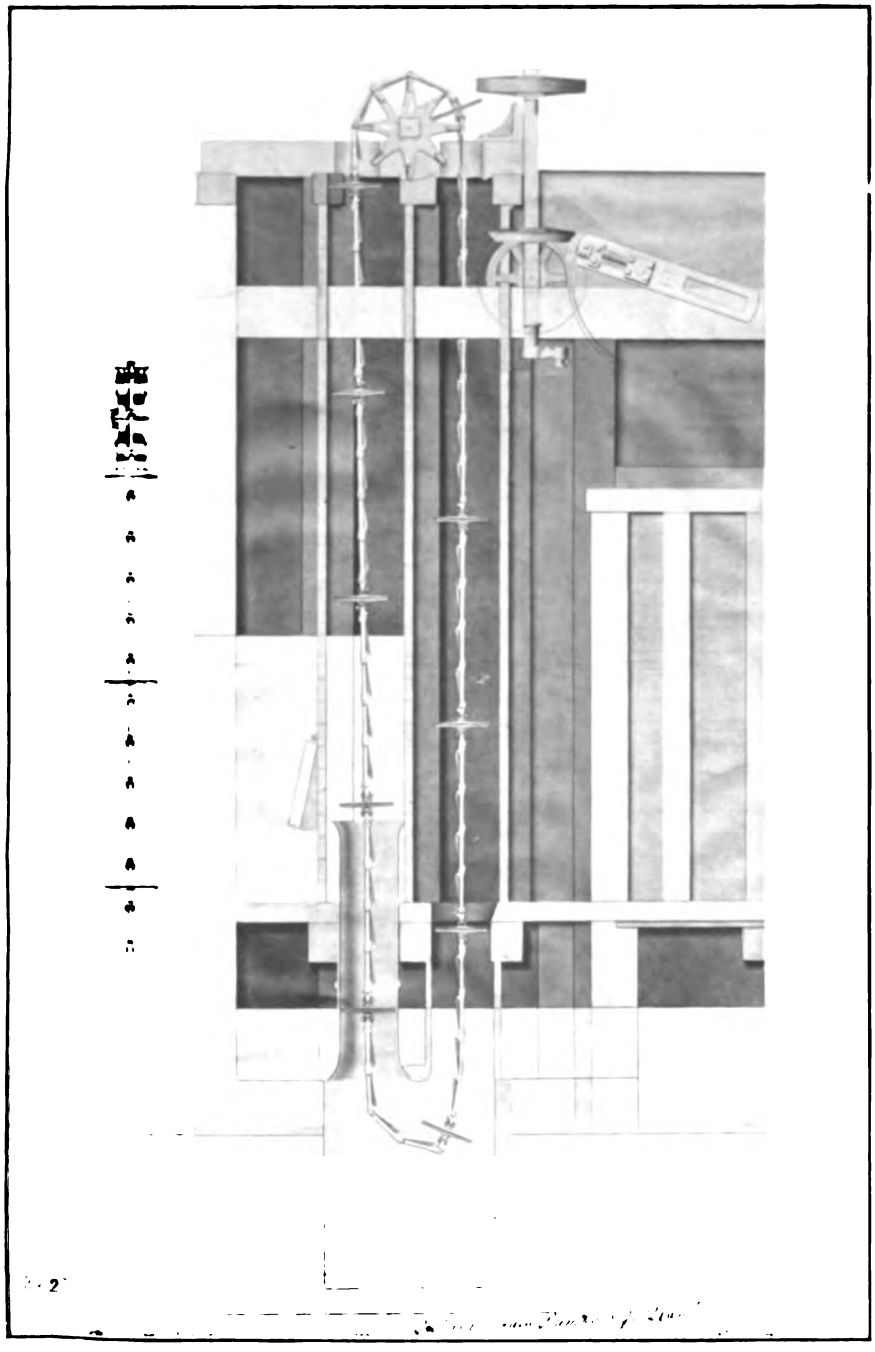
PLATE II.



ELEVATION OF 2-FT. CHAIN PUMP AT PORTSMOUTH DOCKYARD.

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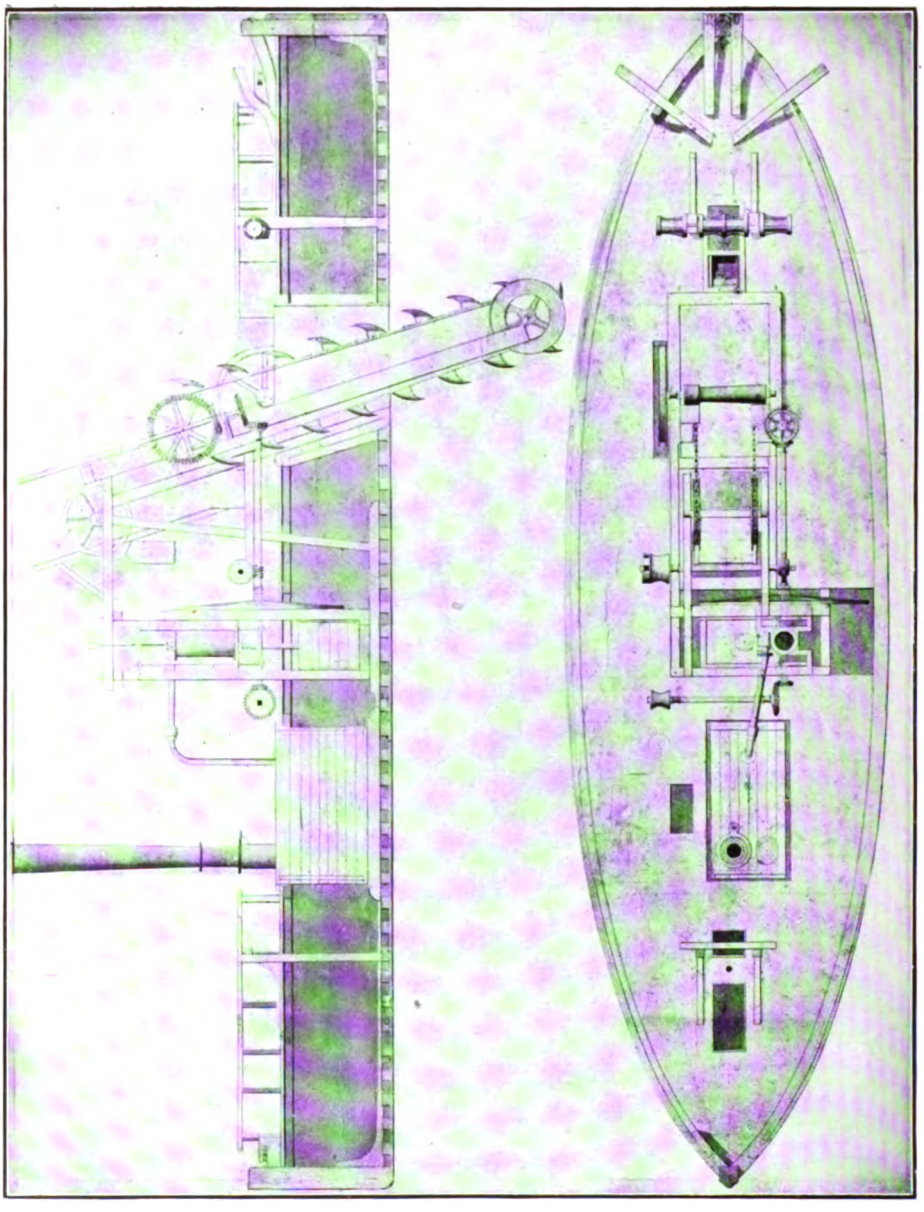
PLATE III.



STEAM DREDGER, 1803-6, AT DEPTFORD DOCKYARD.

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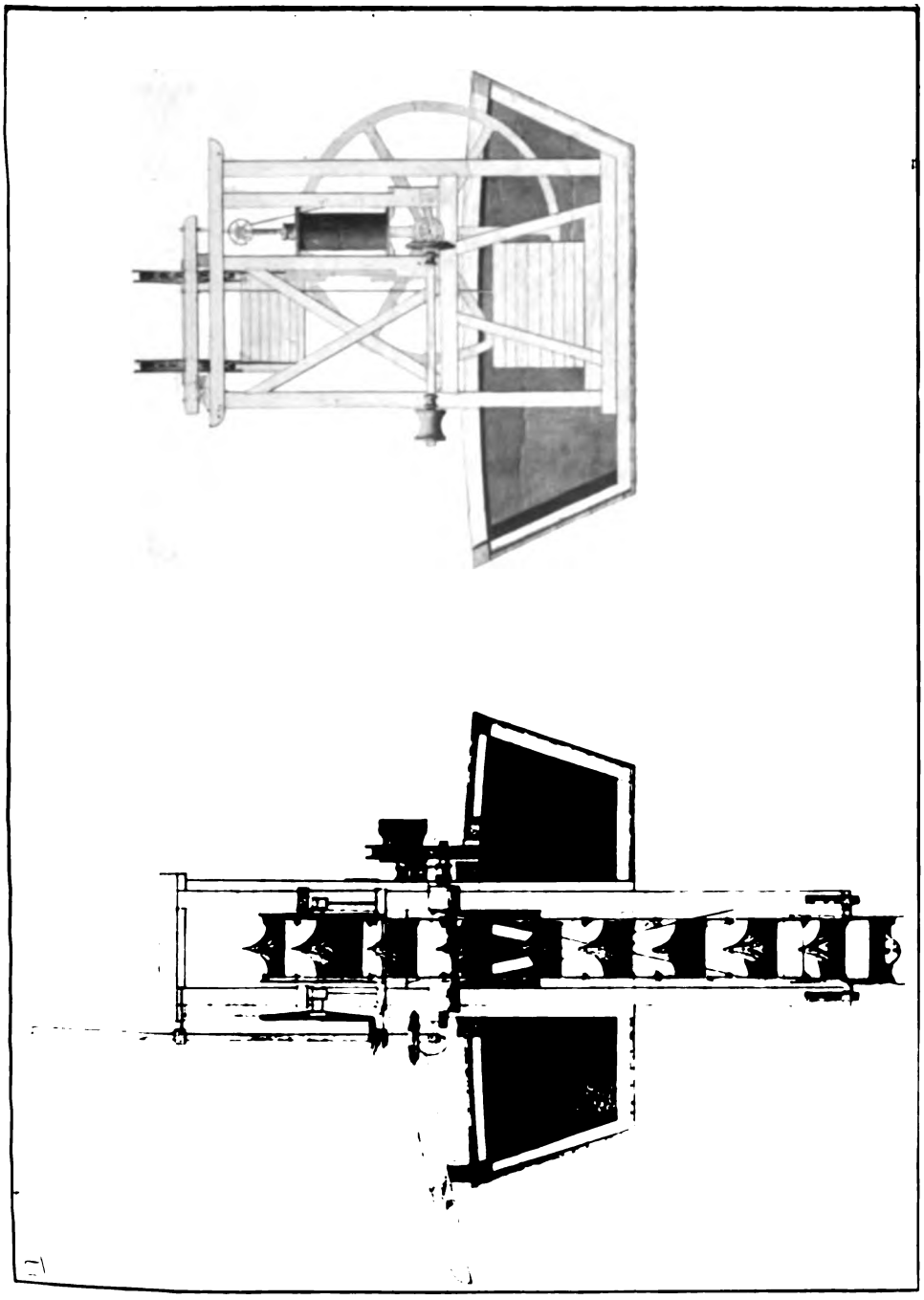
PLATE IV.



CROSS SECTIONS OF STEAM DREDGER, 1803-6, AT DEPTFORD DOCKYARD.

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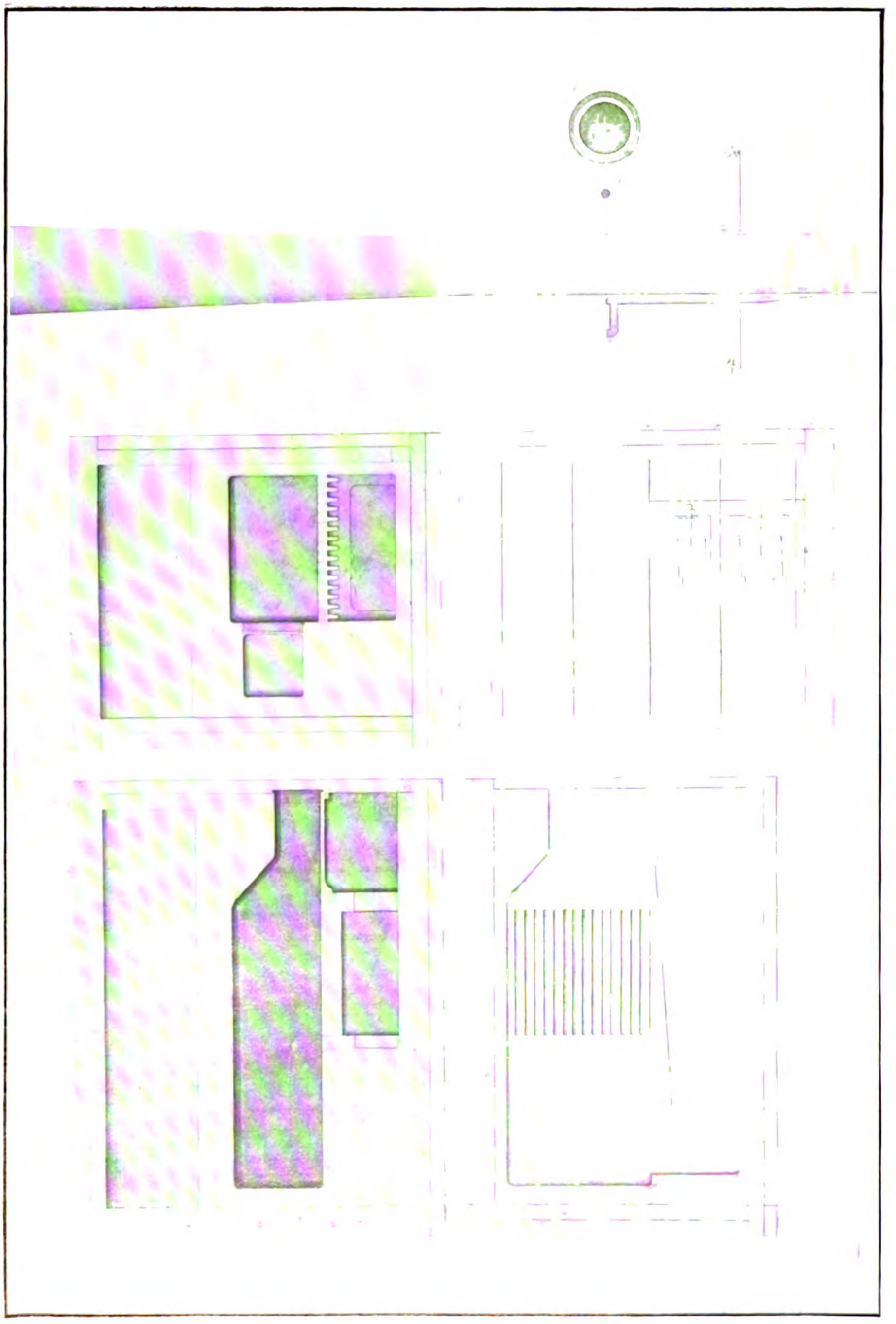
PLATE V.



WOODEN BOILER FOR STEAM DREDGER, 1803-6, AT DEPTFORD DOCKYARD.

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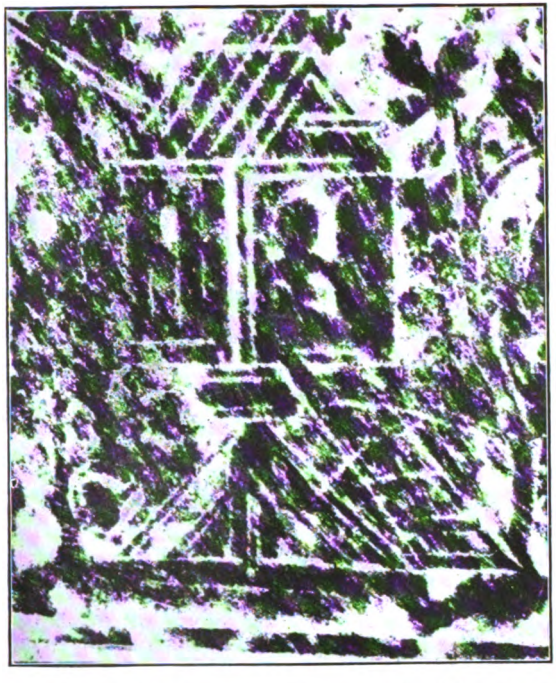
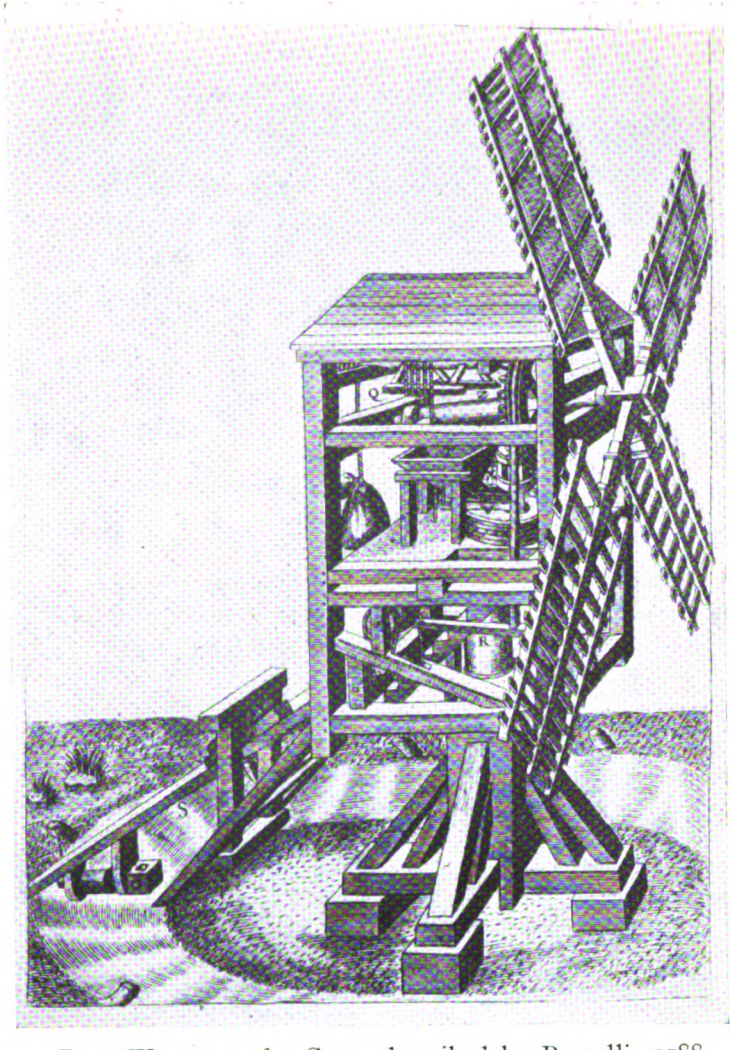
PLATE VI.



POST WINDMILL on Brass of Adam de Walsokne (d. 1349), King's Lynn Church.



POST WINDMILL for Corn, described by Ramelli, 1588.

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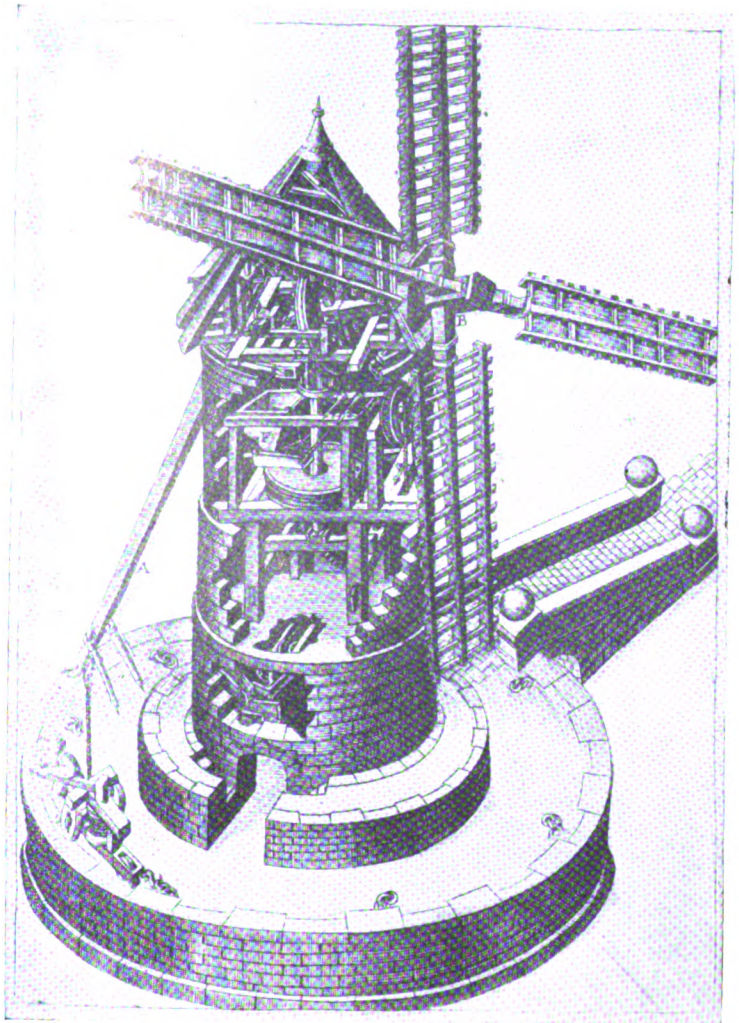
PLATE VII.



TOWER WINDMILL for Corn.

TOWER WINDMILL for Chain Pump.

Described by Ramelli, 1588.

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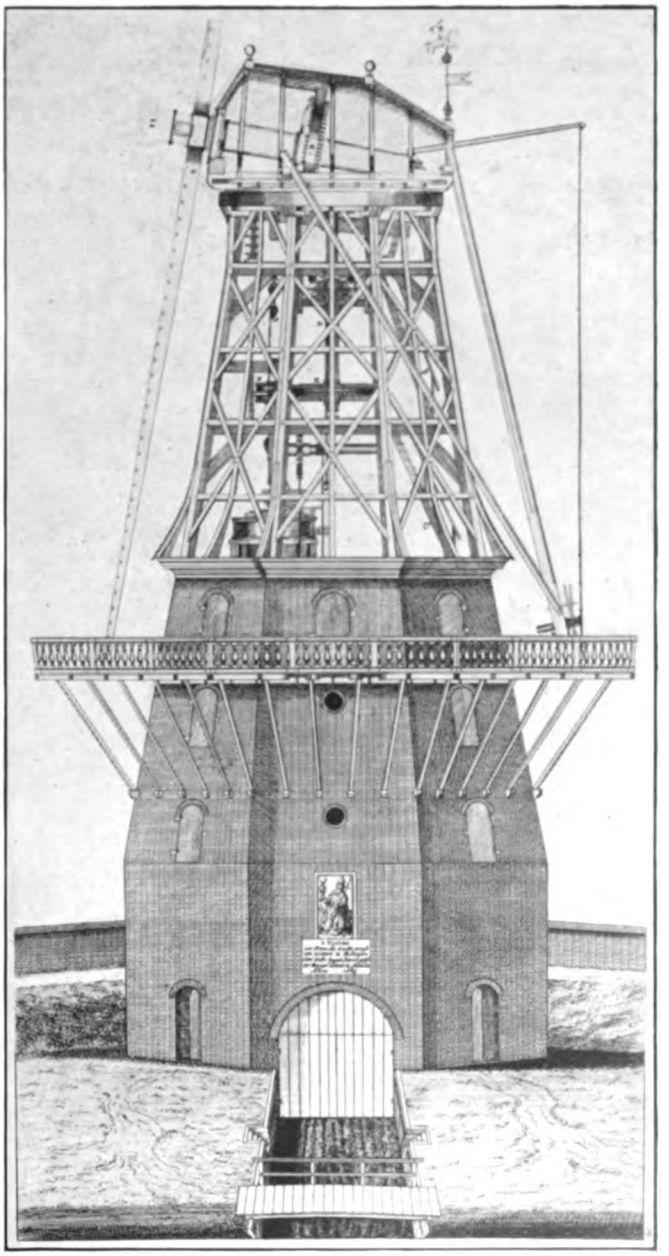
PLATE VIII.



TOWER WINDMILL for Corn at Amsterdam.
Described by Linperch, 1727.

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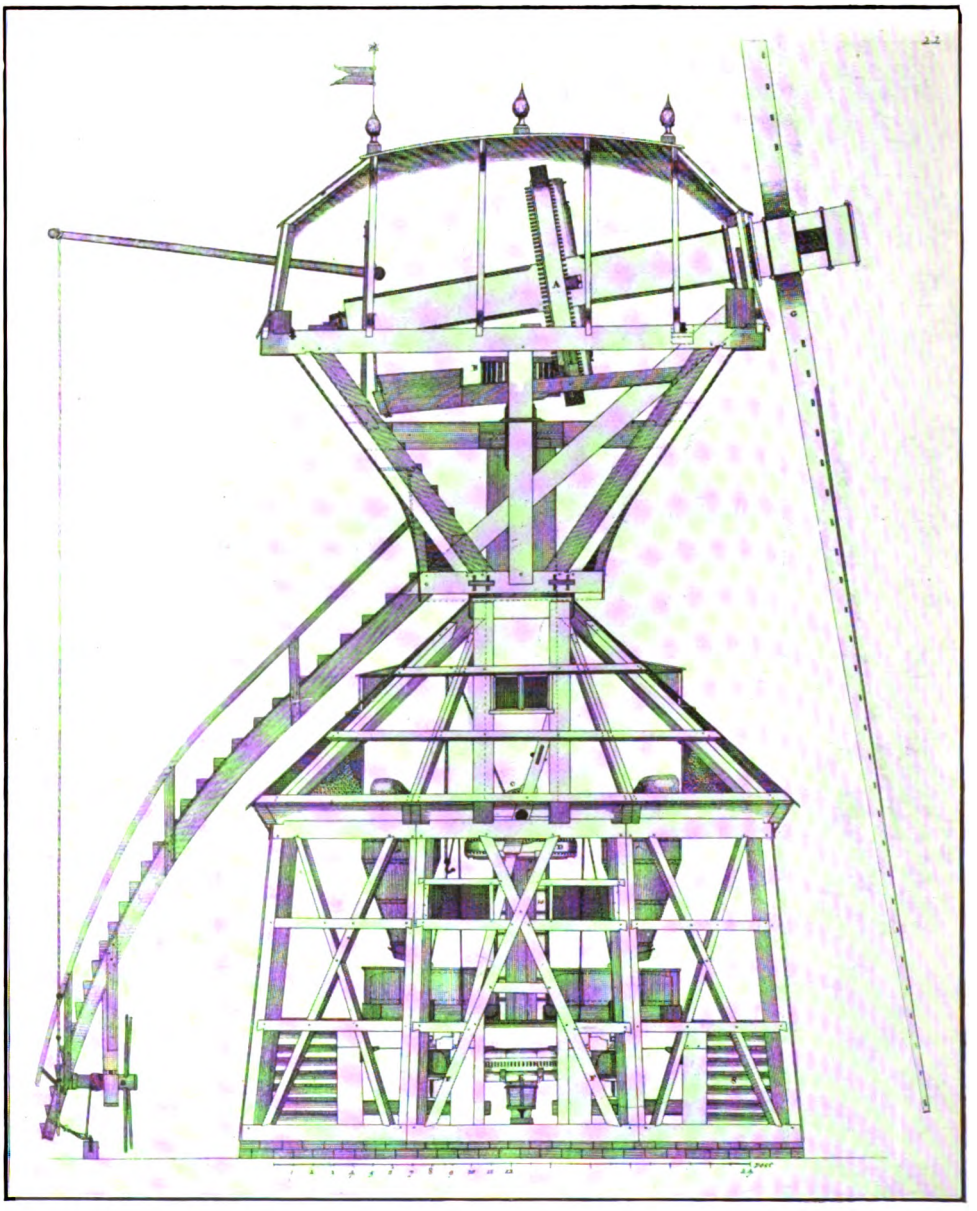
PLATE IX.



HOLLOW POST WINDMILL for Corn at Stockholm.
Described by Linperch, 1727.

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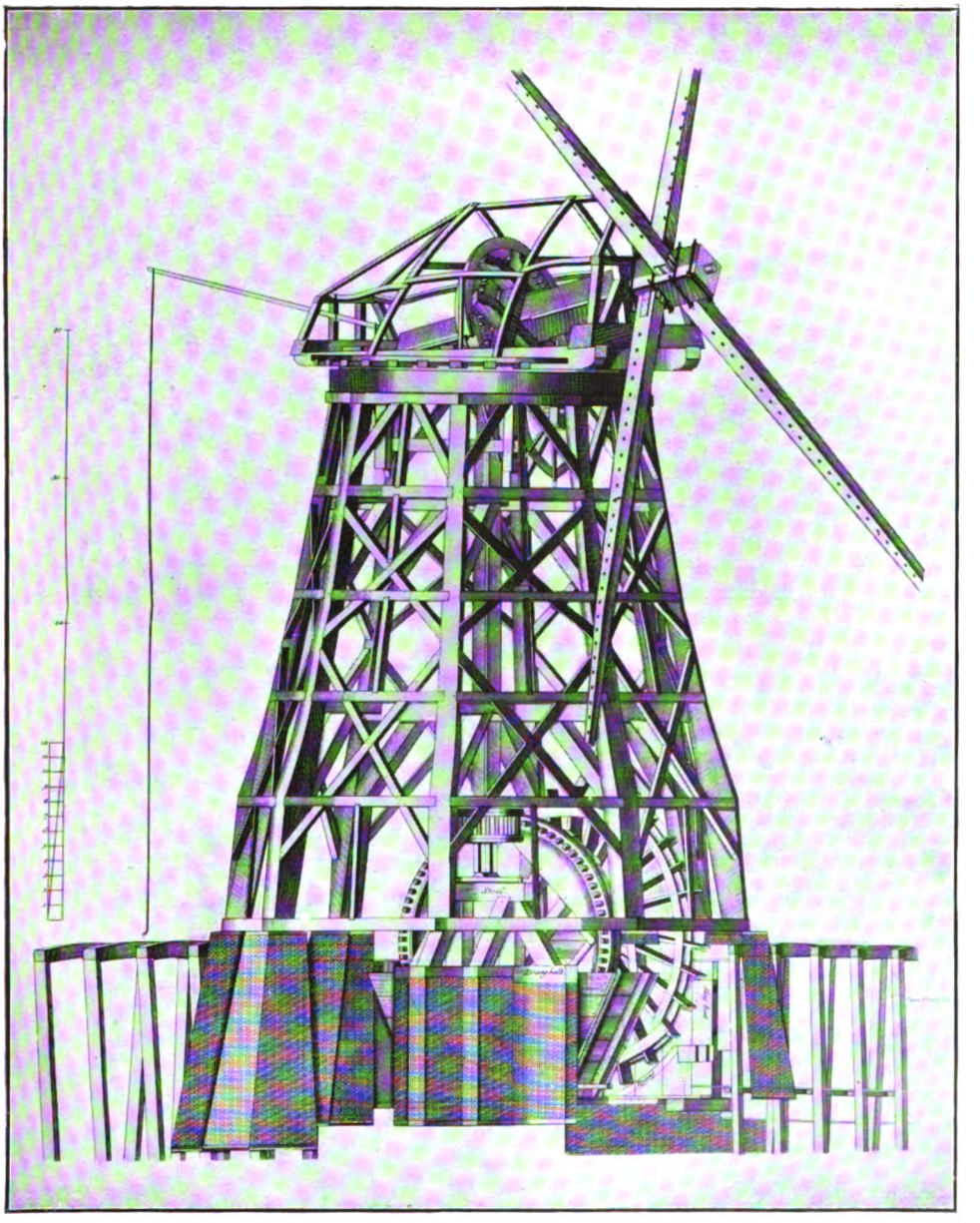

TOWER WINDMILL driving scoop wheel at Beemster, North Holland.
Described by Van Natrus, 1734.

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FIG. 1.—The pattern to be drawn pounced on the cloth, and a small portion of it outlined in black dye.

FIG. 2.—The whole pattern outlined in black and red, the red lines being only coloured alum mordant for red dye.

FIG. 5.—Some portion covered with wax preparatory to dyeing in blue.

FIG. 6.—The cloth cleared of the wax after it has been dyed with indigo.

STAGES IN THE PROCESS OF INDIAN COTT

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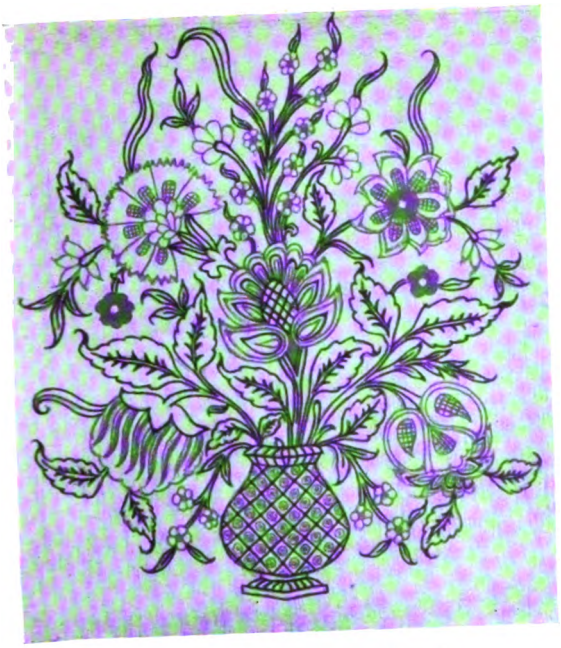

Fig. 3.—The first dyeing in red.

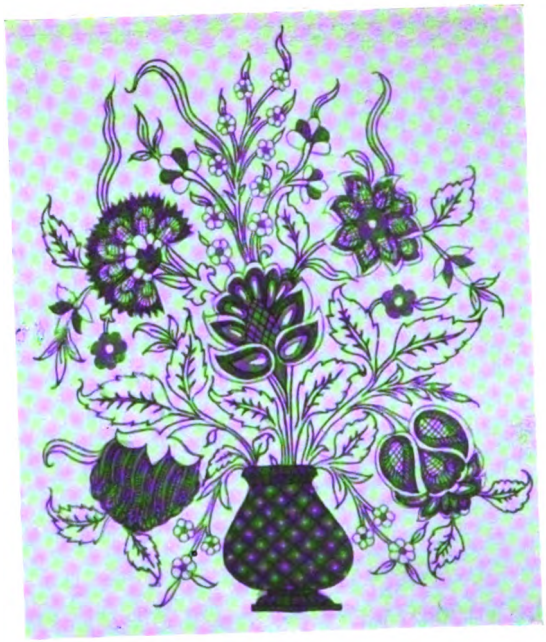

Fig. 4.—The cloth dyed a second time for light red and purple, and partially bleached.

Fig. 7.—The yellow dye added, and the whole work completely finished.

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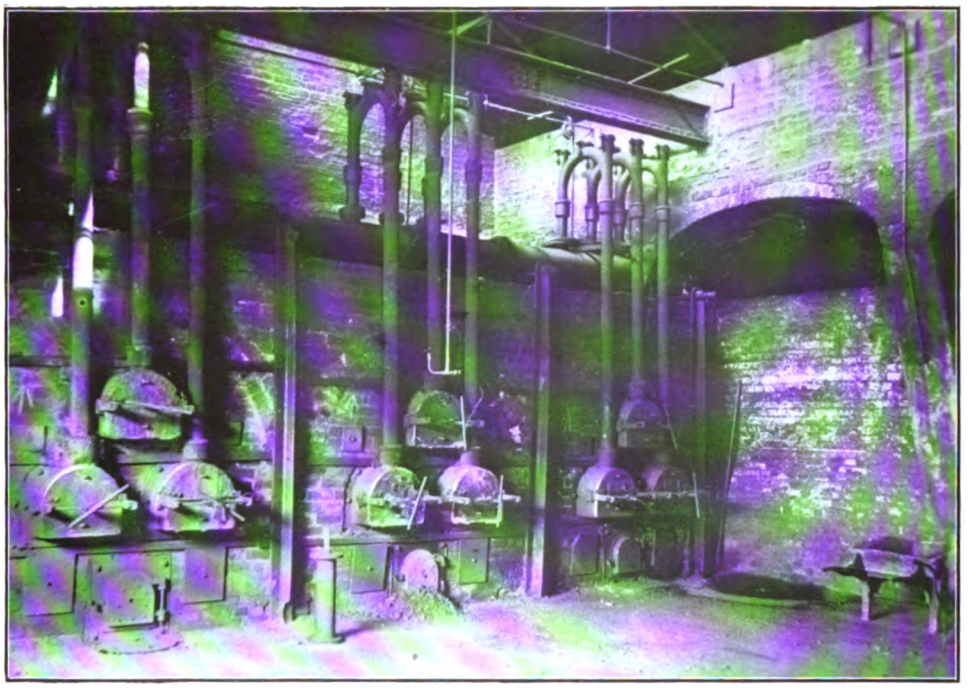

FIG. 1. MURDOCK'S GAS PLANT AT SOHO FOUNDRY.

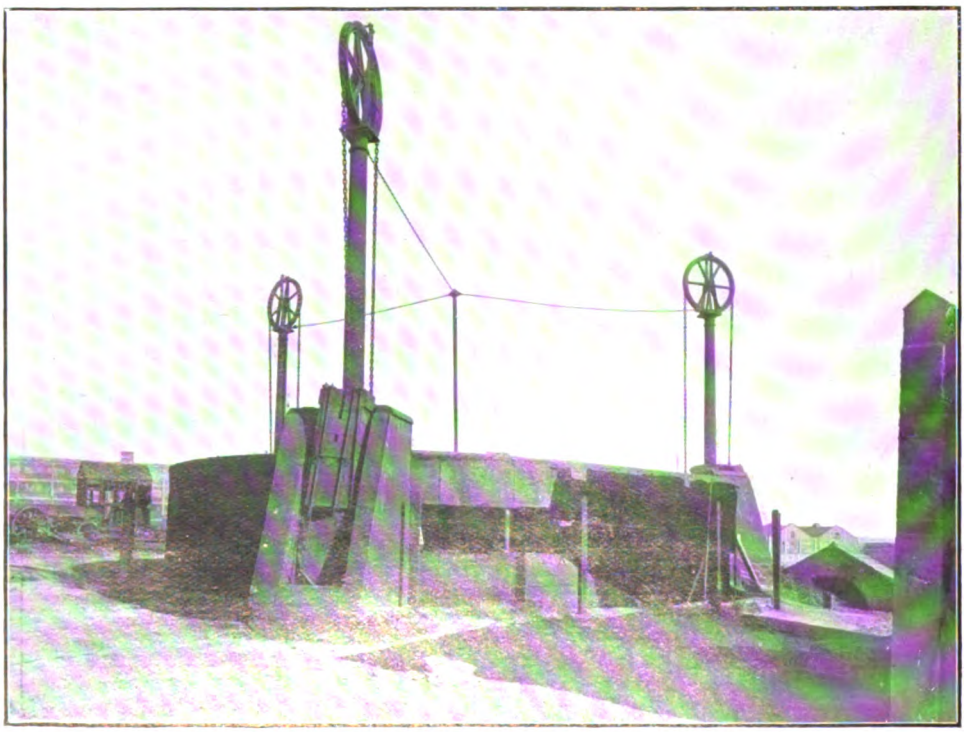

FIG. 2. MURDOCK'S GAS-HOLDER AT SOHO FOUNDRY.

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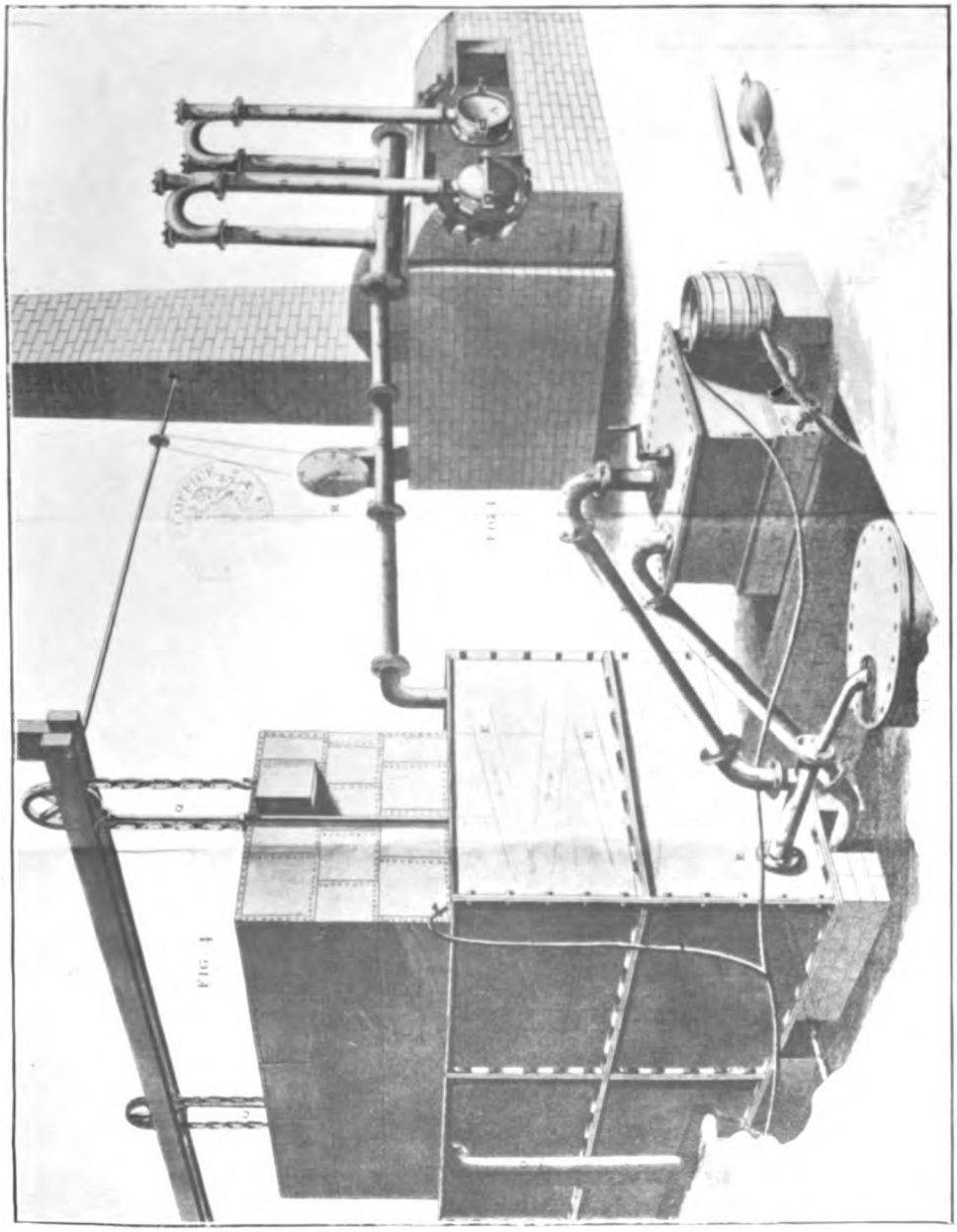
PLATE XIII.



CLEGG'S COAL GAS APPARATUS FOR FACTORIES.
Described by Accum, 1815.

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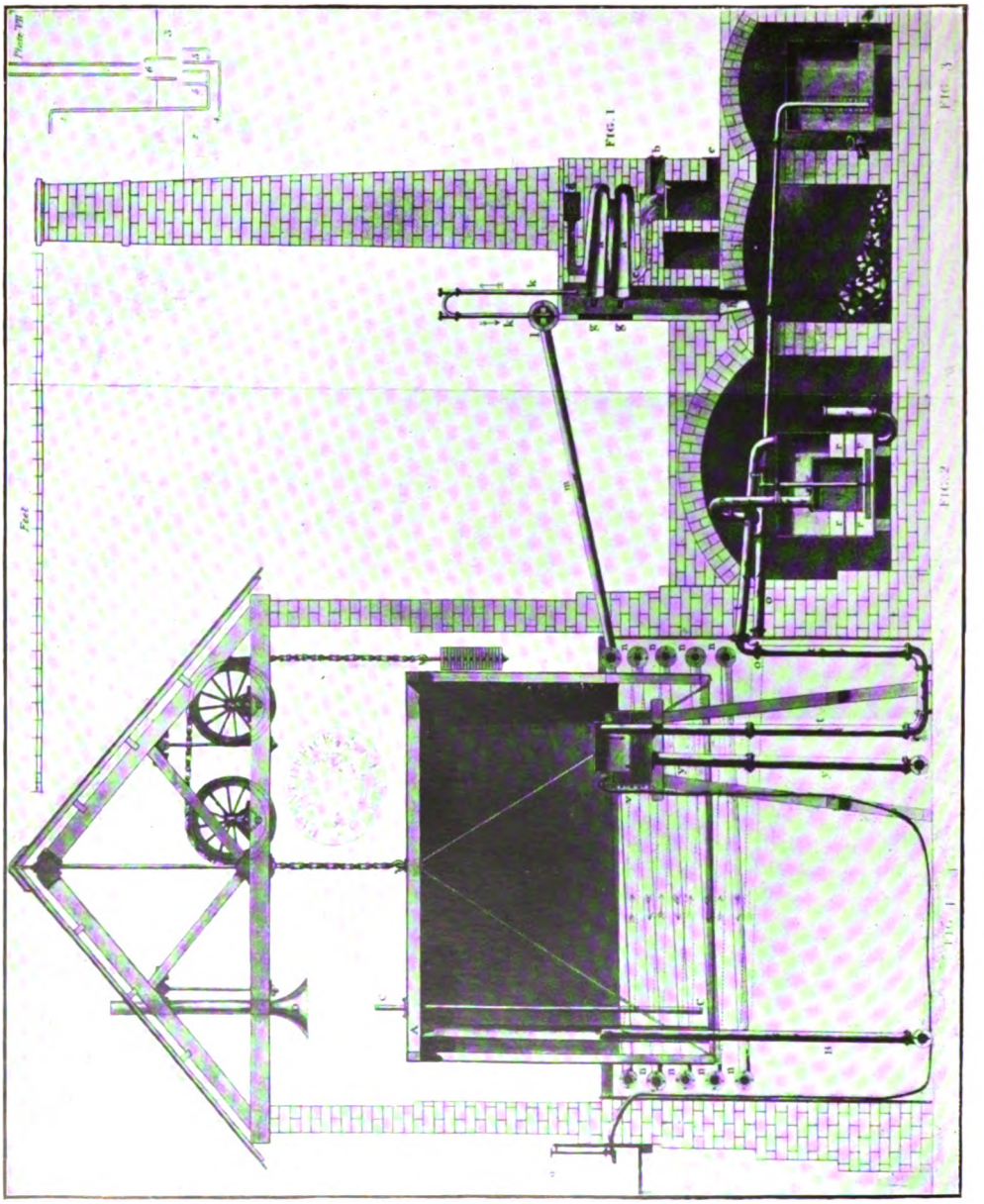
PLATE XIV.



COAL GAS PLANT FOR TOWNS. Described by Accum, 1815.

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PLATE XV.

Yours truly
Geo Cayley

SIR GEORGE CAYLEY, ÆT. 72.

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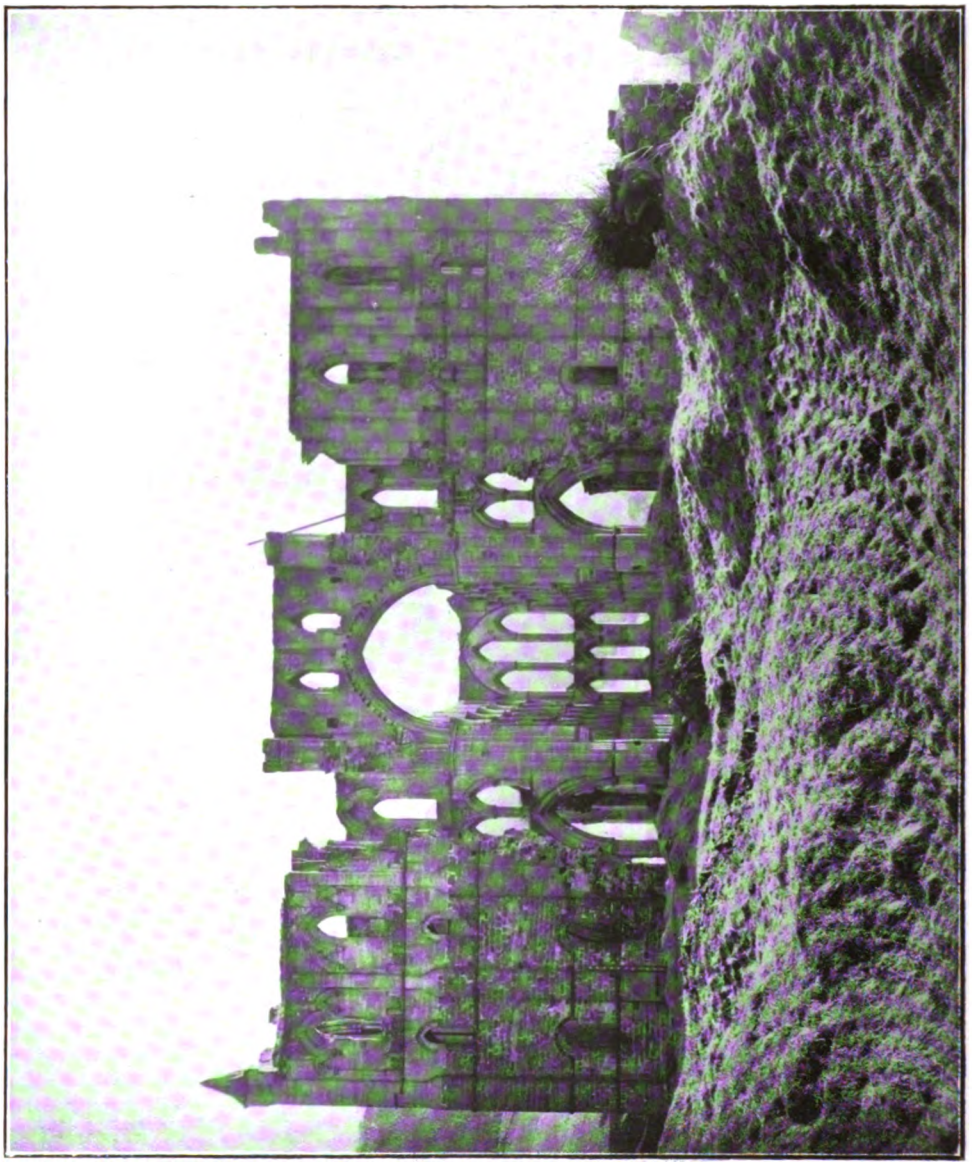
PLATE XVI.



RIEVAULX ABBEY, YORKSHIRE, looking East, before Excavation.

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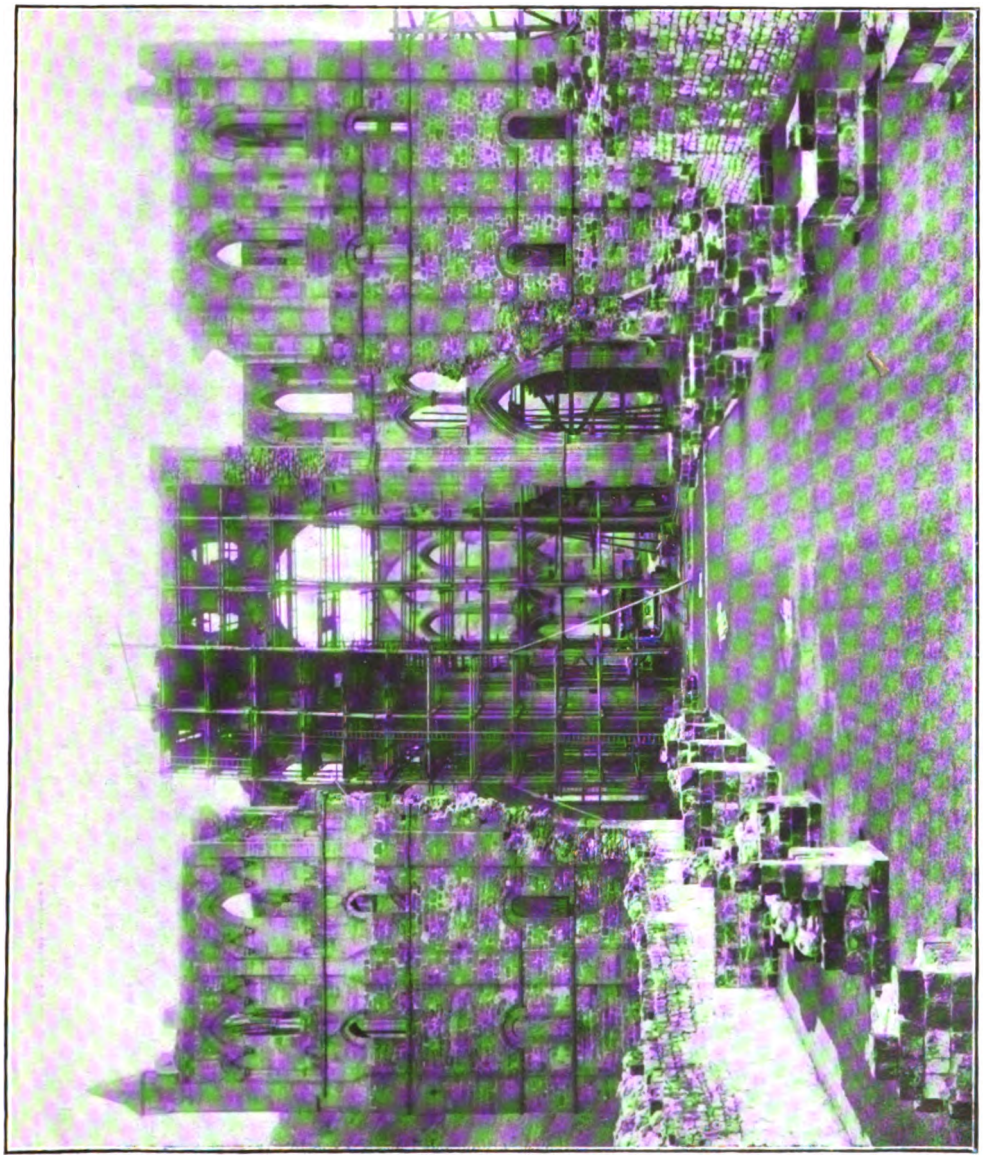
PLATE XVII.



RIEVAULX ABBEY, YORKSHIRE, looking East, after Excavation, 1922.

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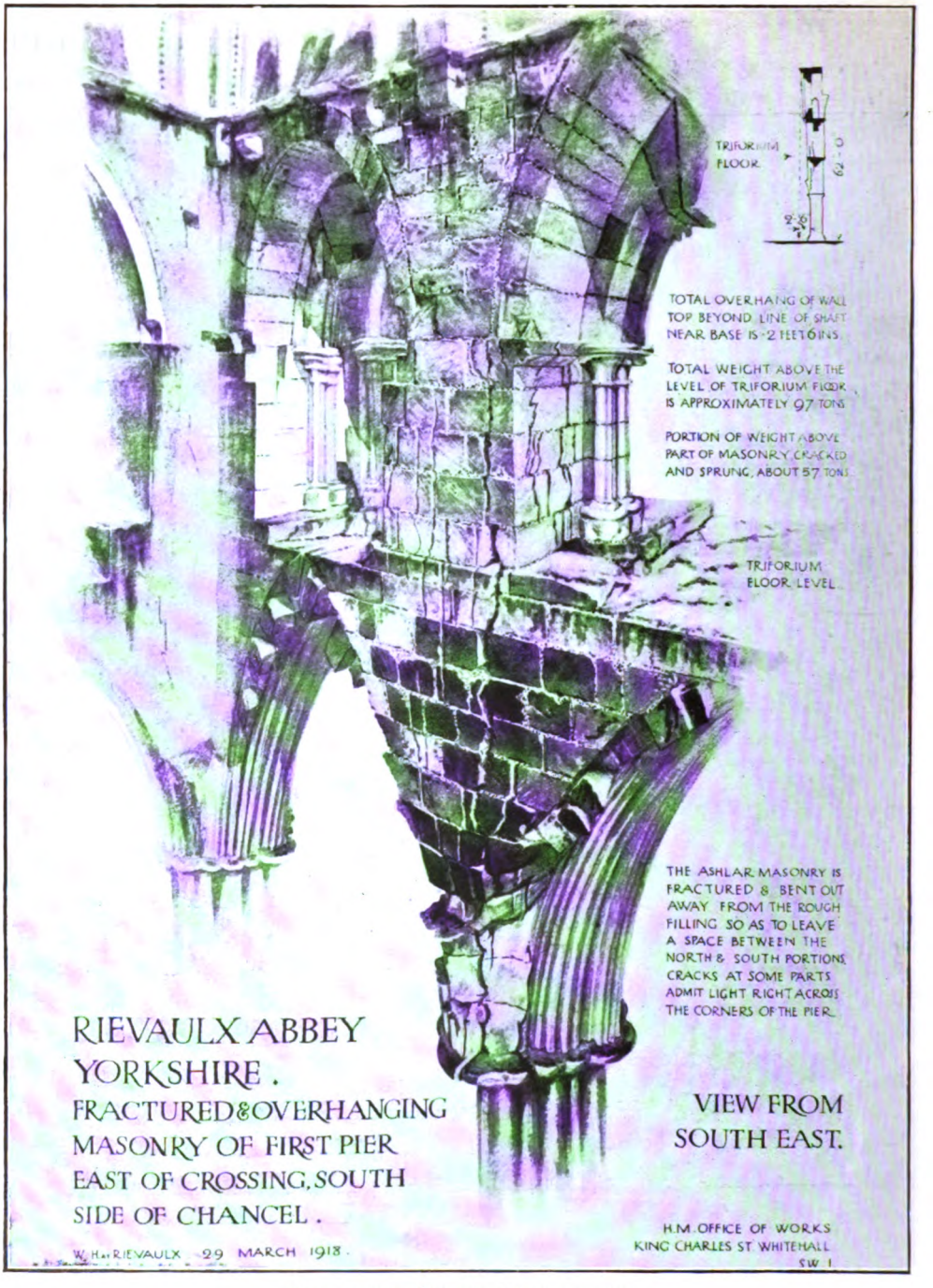

RIEVAULX ABBEY, YORKSHIRE,
from South-East, showing Masonry of Pier south side of Chancel.

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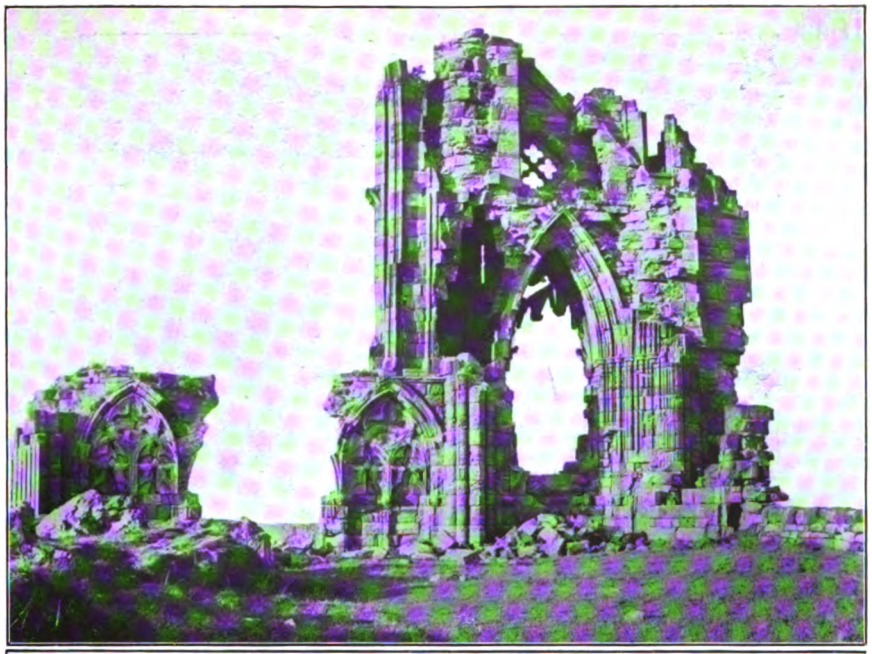

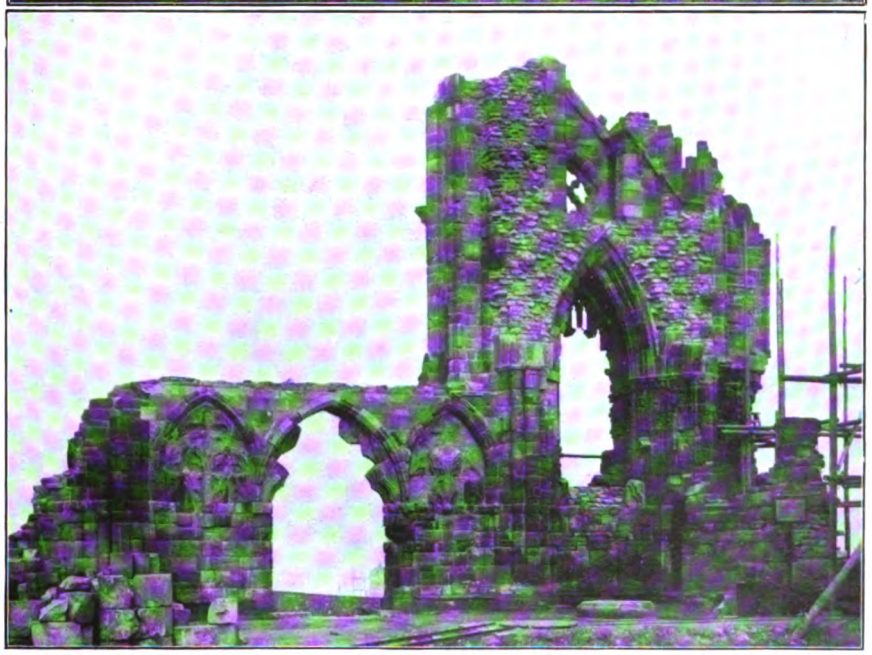

WHITBY ABBEY, YORKSHIRE. West Wall after Bombardment.
WHITBY ABBEY, YORKSHIRE. West Wall after Reinstatement, 1922.

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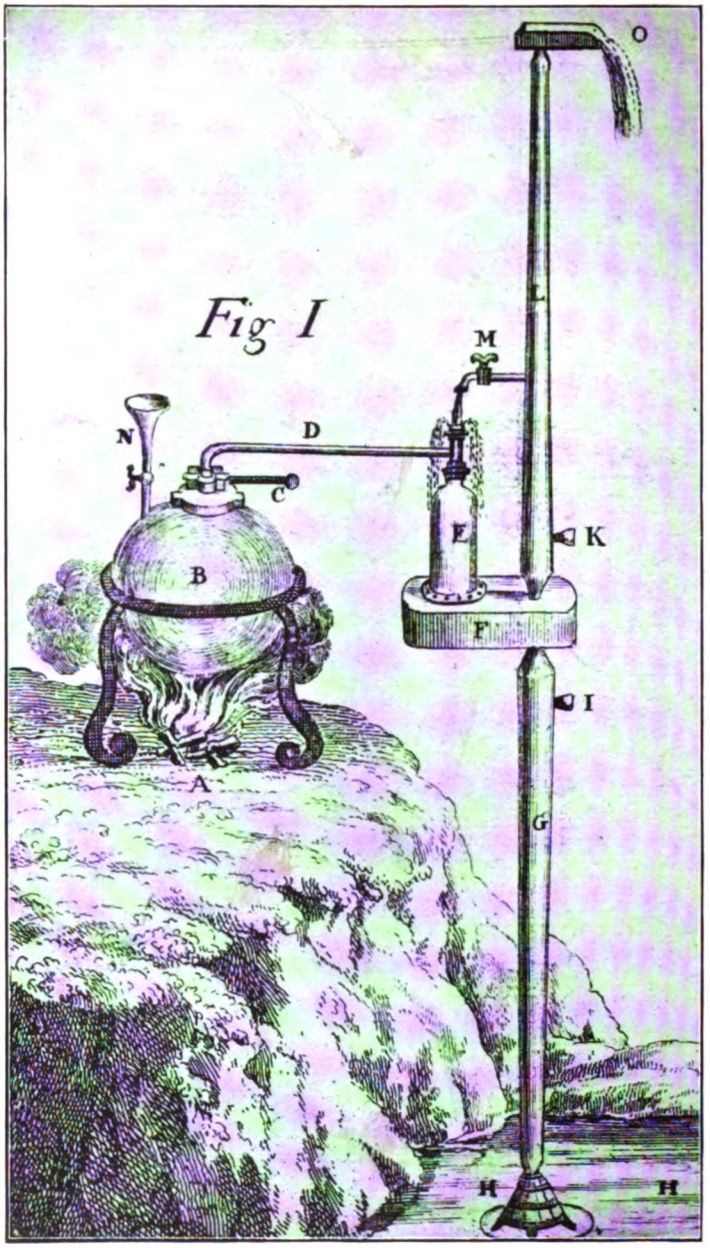

SAVERY'S STEAM ENGINE AT KENSINGTON. Described by Bradley, 1718.

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in concluding that in the true spirit of philosophy you are anxious to hear (or at least willing) even the doubts of one young in the subject of these be the smallest possibility that they will either correct or confirm previous views

The rotation of the magnet seems to me to take place in consequence of the different particles of which it is composed being put into the same state by the passing current of electricity as the wire of communication between the voltaic poles, and the relative position of the magnetic pole to them. Thus the little arrows may represent the progress of the electricity; then any line of particles parallel to them except that line which passes as an axis through the pole (represented by a dot) will be in the situation of the revolving wire and will endeavour to ~~[illegible]~~ revolve round the pole and as all the lines act in the same direction or tend to go one way round the pole the whole magnet revolves. That this is the way in which the magnet revolves is I think evident from the consideration above; from the revolution being in the same direction as with the wire and from the following analysis of the experiment. Took a piece of copper wire similar in form to the magnet and having floated it upright in mercury placed a little cup on the top to contain a globule of mercury and then connected the voltaic poles just as they were with the magnet then placing the pole of a strong magnet beneath the cup containing the mercury. It when exactly in a line with the axis of the wire made

PAGE OF HOLOGRAPH LETTER OF FARADAY, 1821.

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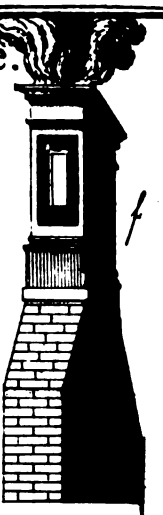

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THE NEWCOMEN SOCIETY

for the study of the history of

ENGINEERING and TECHNOLOGY

TRANSACTIONS

Volume IV

1923-1924

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1925

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EMBLEM OF THE SOCIETY.

The emblem shown on the cover was adopted by the Council in 1923 after much deliberation. The griffin is emblematic of vigilance, and is represented as looking back while yet going forward. The motto is due to Col. Kitson Clark, M.A., and may be rendered " Mindful of what has been done, we strive at the same time after the things yet to be done "; or, more freely and tersely: " Let us think backward and look forward." The design was cut in wood by Mr. Alec Buckels, A.R.C.A.

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PRESIDENTIAL ADDRESS.

The Value of Technological History,

BY

Loughnan St. L. Pendred, M.I.Mech.E.

(Delivered at Prince Henry's Room, Fleet Street, E.C., Oct. 26th, 1923.)

The burden of the address which it is my privilege to present to you this evening is the value of the kind of work upon which the Newcomen Society is engaged. It may be said, I venture to think, that few of us when becoming members of this Society ever asked ourselves whether the history of Engineering and Technology had any value at all. We knew it interested us, we knew we were subject to the charm of ancient things, and that was sufficient for us. But others, outside our little fold, are in a different state. They twit us with wasting our time over musty records instead of spending it profitably on modern developments; they ask us "What use is your Society; what good end does it serve?" You will see as I proceed that, after all, I can answer that question only partially if by the word "use" is implied the "use" that brings money. That is not use but usury, and the work of the Newcomen Society cannot, we are all proud to say, be put out to that employment. There is, I am convinced, a higher use of technological history, and to it I shall endeavour to direct your attention to-night. Perchance, if you are kind enough to accord this address the honour of print, it may convert here and there one or two doubters, and bring nearer a recognition of the real value to all nations, of the study of the history of the technology on which their advancement depends, and to which they look for their very existence.

Let us ask ourselves, in the first place, what are the objects and intentions of general history? Why has it been regarded for hundreds of years as an essential acquirement of the educated man? Why has it attracted the attention of great brains of all countries and in all times; why do we accord to historians a position of exceptional honour? Can we show that general history has any practical, material, money-making value? I doubt it.

Frederic Harrison placed in the forefront of a collection of essays one entitled "The Use of History." He devoted to it, no doubt, the great knowledge of historical literature which he possessed; but it remains unconvincing. His argument appears to be "We are what we are because of all that has happened; therefore to understand the present we must study the past." That is not strictly true; we

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may play chess well without having mastered Forbes's History of the game; we may administer matrimonial laws intelligently without having read Froude's Henry VIII. The value of history is something different from usefulness. Harrison wrote "We are so deeply indebted and so indissolubly bound to preceding ages, if all our hopes of the future depend on a sound understanding of the past, we cannot fancy any knowledge more important than the knowledge of the way in which this civilisation has been built up. If the destiny of our race, and the daily actions of each of us, are so completely directed by it, the useful existence of each depends much upon a right estimate of that which has so constant an influence over him; will be advanced as he works with the working of that civilisation, above him and around him; will be checked as he opposes it; it depends upon this, that he mistakes none of the elements that go to make up that civilisation as a whole, and sees them in their due relation and harmony." I think Frederic Harrison meant here a higher use of history. He meant that historical knowledge enables men to live fuller, more understanding lives; not that, as I have said, history can be put out to usury, that it is of use in the same way that knowledge of the multiplication table is of use. That cannot be shewn of general history, it can only be shewn dimly of technological history.

But it is, I submit, better that we should not attempt to define the uses of history within terms that would satisfy those who cannot sympathise with the work on which our Society is engaged. The most desirable things in the world, the things for which we most justly honour their creators, are those very things to which it is impossible to assign a practical value. Painting and architecture, music, the higher astronomy, poetry, transcendental physics, beauty and harmony in all their forms. Of what use are they? They are not to be priced by the common standards of market-place utility. They are not to be measured by yards or weighed by avoirdupois, they are not to be submitted to "acid tests" or assayed against a gold standard. We know without being able to define it that they make for good, that men are more tolerable creatures to themselves and to others when they know something of these useless things, these things that can not be let out to usury. Let us class history with them. "So long," says Craik, as one mind differs from another, there will always be much difference of sentiment as to the comparative claims upon our regard of that, on the one hand, which addresses itself principally to the taste or the imagination, and that, on the other, which makes its appeal to the understanding only. But, we are not to suppose that, because the epithet useful is commonly confined to the latter, the former is to be deemed useless. We call that, by way of distinction, useful which is *merely* useful. The agreeable or the graceful is plainly also useful. It is useful and something more."

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You see, gentlemen, that I am prepared to give up any attempt to prove that historical research is useful in the same way that technological research is useful. But I am not prepared to say that it is therefore without value. On the contrary I am convinced that it has a higher value than technological research because it touches in us all something greater than our bodily comforts and amenities. But even from a purely practical aspect we might show that it has its value—as, for instance, in the control of patents. For purposes of education in science and technology it has, I believe, advantages which have not yet been properly explored, though those of you who are familiar with the Mechanics of Mach may recall how the author leads us up to complex thoughts by the logical method of pursuing their evolution. Of the utilitarian aspect of the history of engineering and technology I shall have more to say, but for the moment let us surrender all claims to industrial usefulness and ask ourselves if we may not place our efforts at least beside those of sociological and political historians.

It is sometimes imagined that the purpose of history is to bring the past before the present. I conceive that it is no such poor peep-show business, and that history and archaeology would never have won to that position which they hold in the esteem of intellectual men were there no more in them than that. The real importance of history resides, I venture to suggest to you, in its evolutionary characteristics. It is not merely a series of disconnected pictures of the past but a complete and uninterrupted account of the development of human thought and feeling, of human institutions and human work. It is the consecutive nature of history, to put it briefly, that makes it valuable. Was it not Kelvin who once said of a particular science that it was " in the natural history stage " meaning thereby that it was no more than a series of facts without organised connection. In the hands of Darwin, natural history was raised to a much higher plane because a general purpose and a consistent movement in it was revealed. Men may collect a number of facts about any given subject, but they remain just interesting facts and no more until they are laid down in a logical sequence and some great generalisation or law is based upon them. The arrangement of the elements in a series by Mendeleeff may be cited as a familiar example. Before his time the order of the atomic weights had no purposeful meaning, after it the wonderful harmony of chemistry raised that science to a higher plane.

Can we then say of technology that it has a connected history? If we can, then we have found a basis on the merit of which we may claim for that history a position beside all other great histories. We may claim for it on this ground alone that it is a proper study for intellectual men, that it will broaden our ideas and enlarge our minds; that it reflects one of the endeavours, probably the most important endeavour, of man from the beginning and is therefore a proper study for mankind. " There is," said Lord Acton, " wisdom and depth in the

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philosophy which always considers the origin and the germ, and glories in history as one consistent epic." Now of this continuity there can be no manner of doubt. Just as philosophers are convinced that in natural science there are no gaps that, in the words of Buckle, "the material world presents one vast and uninterrupted series, gradually rising from the lowest to the highest forms, but never stopping," so, I venture to suggest to you, are the inventions of man. For our convenience we may divide them into families and classes. We may separate mechanical engineering from civil, electrical and chemical engineering, we may put our industries in compartments and divide the inventions of boot-making from those of lace-making; we may find separate niches for the machinery of transport by land, by water and by air, we may set up partitions between the classes of machinery that prints our newspapers, hammers out our guns, stamps our money, operates our huge docks and carries us over land, sea and air. We may adopt the classification under the numerous heads which facilitate the work of the Patent Office. All this we may do for our convenience, but a discursive imagination will perceive that all are united by certain common bonds, that the passage from one to another is *per gradum* not *per saltum,* and that there is a complete and unbroken net which combines into a single scheme every invention which has come into the mind of man since the first stone axe was made or the Sussex chalk was chipped with a reindeer horn.

"Exactly," says Mason in his *Origins of Inventions,* "as one sees in the natural world in geologic time plant and animal forms becoming more and more highly organised, so in the construction proceeding from men's minds and hands there has been a corresponding development, increased complexity and multiplied functions. In fact, the history of industry is the story of the great diversity of materials used, of the more complicated thought in the mind of the inventors, of the perfection of tools and processes, which take the place of hands and feet and brain, and, lastly, of the final causes of the products of men's brains and hands." Again, he says, "there is a close analogy between the natural history of the kingdoms of nature and the unfolding of the arts of life. The methods of studying the one may be successfully employed in a search for the true history of the other," and again, "the unfolding of the genius of the ages has been the evolution of invention from the beginning."

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With these high views of invention, you will all be in full agreement. It is through a constant recognition of them, both implicit and explicit, that we shall raise this Society to the position it merits in the minds of men. The history of industry is the history of invention, and can any intelligent being assert for one moment that the development of man, since he became man, is less worthy of serious attention, is less worthy of honour and respect than the investigation of

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those natural causes by which man himself was developed from a lower creation? So fully has it been recognised since the intellectual development of the world began that we cannot draw a line through our investigations at the Garden of Eden, that hundreds of philosophers have examined, analysed, and scheduled the progress of human thought; but, strange as it will seem in the future, the development of material inventions has never received and does not receive a modicum of the attention that is paid to the various philosophies. Strange because technological progress has made far more difference to the world than philosophies have made. Even religious toleration owes as much to the advance of locomotion as to the work of scholars. I apprehend that human intellect changes very slowly, if at all. The ability to think which is the beginning of intellect, and the ability to imagine which is the furtherance of it, were as highly developed in the Greek philosophers as in Black, Davy or Kelvin. The intellectual difference between the past and the present is in the accumulation of facts. The laborious inquisition of natural laws, the heaping up of experimental observations, the slow secular progress from one form of invention to another—these are the things which distinguish the thought of to-day from the thought of yesterday. And every one of them is related, always in some measure, in some cases, intimately, to some technological development. We may venture to say that under the technological conditions which prevailed in ancient Greece no other kind of thought than that which that period gave us was conceivable.

There is, I suggest to you, this important difference that whereas human thoughts are always the same, human inventions are continually changing. Within the limited compass of human experience the nature of men and women remains, as far as we can see, constant, and the power and direction of their thoughts vary but little, if at all. How different is this from the ever developing, ever changing, ever growing nature of inventions. They slide step by step from the simple to the complex, carrying themselves forward rather than being carried onwards by man. The "Rocket" of the Stephensons and Booth was the natural descendant of the locomotives of Hedley and Trevithick. Each successive step was made under the compulsion of the machine itself. Man's power of invention is very limited; his power of thinking will not permit him to take a long step at any time. A few with greater vision see possibilities but their feet are hobbled by a short rope and they can only crawl where they would gallop. The rise of the motor car is a surprising example. By the year 1897 engineers had accumulated a great mass of experience of machinery in general, and tractive machinery in particular. Yet consider the mistakes that were made, the persistent under-valuing of the engine power required, the constant failure of parts, the inefficient grouping of the members. We have only to ask ourselves if any man, even in his dreams, ever visualised such vehicles as we see to-day (little more than

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twenty-five years after the coming of the car) to comprehend how far the original inventors were from satisfying the actual needs.

We must notice in this connection that all the elements of mechanical inventions were discovered years ago. How old is the crank, the reciprocating piston, the gear wheels, the cams and the links of all kind that are pawns with which we work out new combinations? I cannot call to mind a single modern invention that has some wholly new mechanical device equivalent to the crank, the eccentric or a pair of toothed wheels, something that was not adumbrated years ago and of which the advancing shadow may not be seen in traditional usage or in the record of patents for mechanical inventions. By taking thought man may add a cubit to his mental stature, but no more than a cubit. He must build his edifice brick by brick; even the greatest rarely bring in their arms a vast corner stone. The gamut of human invention increases indeed, but the intervals between the notes is no greater now than in the days of the Greek and Roman engineers.

I would like to have presented a single chapter of the history of inventions, but time does not permit. It must suffice to ask you why did the Stephenson or Howe link motion not leap to the eye of the early engine builders? Why had the development to proceed through the single fixed eccentric, then the slipping eccentric and gab motion, then the two eccentrics with their horned gabs—the Carmichael gear—until the obvious course of connecting the two eccentric rods by a link was discovered? The answer to my mind, is that the mechanism led the thought onwards; that man could not make—simple as it may appear to us now—the long jump from one fixed eccentric to a complete Stephenson reversing gear.

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The theme to which our examination has now brought us is the influence of technology on human development. I am not aware that any historian has done justice to it. John Richard Green must have had it in his mind when he was formulating his "Short History," Buckle felt its influence though he failed to express it, Draper knew it existed but barely touched upon it. Historians of sociological progress have always devoted the greater part of their attention to philosophy; they have given little thought to the effects that a single invention may have upon the rise and progress of nations. It is but natural that they should take that course. The "documentation," as the French would say, for the familiar forms of history is abundant, whilst the documentation for the history of the inter-relationship between technical inventions and human progress is scanty. Some works on social history, such for example, as the Webb's "Industrial Democracy" or Lloyd's "Cutlery Trades," and some biographies, throw patches of light upon it here and there, leaving the rest darker than before. In his Sandars lectures on bibliography at Cambridge, now happily available in book form, Mr. E. Wyndham Hulme, one of our Members, has shown us one way in

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which this large problem may be attacked. The contemporary bibliography of any subject, in some measure, reflects the amount of human interest which that subject has aroused during a given period. It does not, indeed, give us quite what we want, but it does suggest one direction which organised investigation might take.

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I do not want to burden you with quotations in support of a proposition which needs no support in such company as this, but one I must make because it strengthens the view I have been endeavouring to place before you that technological inventions are potent factors in the improvement of the lot of man, and are therefore as fully deserving of recognition at the hands of the historian as conquests and policies. At the public meeting held in 1824 at Freemasons Hall "for erecting a monument to the late James Watt," the Rt. Hon. W. Huskisson was one of the principal speakers. In an eloquent eulogy he said "The economy and abridgement of labour, the perfection and rapidity of manufacture, the cheap and almost indefinite multiplication of every article which suits the luxury, the convenience, or the wants of mankind, are all so many means of creating, in men even but little advanced from the savage state, a taste for improvement, of raising in their bosoms a feeling of new wants and new desires; of shewing them the possibility of satisfying those wants and those desires; and thereby of calling into action the most powerful stimulant and steady motive to advancement in the scale of the civilised world. . . . If the steam engine be the most powerful instrument in the hands of man, to alter the face of the physical worlds, it operates at the same time as a powerful moral lever in forwarding the great cause of civilisation. We cannot, therefore, recall to our recollection the invention of the steam engine, and follow that invention through all its consequences, without feeling the beneficial influence of this discovery upon all nations, from those most advanced to those which have made the least progress, in the arts and refinements of life."

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So far I have endeavoured to present to you what may justly be regarded as the higher aspects of technological history; I have essayed to lay before you the reasons why we may venture to place it beside political and social histories. I have sought to show that it has those qualities which broaden the mind and sharpen the intellect and that it is as essentially human as any other kind of history. These are virtues which it is difficult to define. Speaking of the history of science, as a whole, George Sarton, one of our American members, says "it is the backbone of the new humanism," and another of our members, Dr. Charles Singer, in an introduction to Dr. Ivor B. Hart's *Makers of Science,* exclaims "Surely the contemplation of the condition under which these men—the heroes of science—

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worked and lived, the examination of their training and mental history, of their environment and manner of development, must be of value—even in the practical everyday sense—to those who would follow in their footsteps." All of which is a little vague, a little indefinite. Is there no direction in which we may find a positive value of technological history? Let us see.

We take first its educational value. There is no better method of instructing youths in the higher branches of technology than by leading them step by step through successive developments. The young student of steam engineering, to take an example, is in exactly the same primitive intellectual state with regard to steam as was Papin or Savery. He is therefore in a condition to understand those two pioneers and once having mastered the principle of the raising by water by the condensation of steam, he is in a position to take the next step—the interposition of the piston by Newcomen, and is easily led forward through Smeaton's improvements, and the employment of the " pickle pot " condenser until a state of mind similar to that of Watt's is induced. He is, therefore, able readily to appreciate the separate condenser and can be brought by easy stages to the comprehension of Watt's difficulties about the properties of steam. To follow the simple researches of that great man offers no difficulties to him, but fills him with a gentle excitement as each step is discovered afresh. From Watt to Trevithick is a short jump and the student now finds himself in possession of the fundamental principles of the low pressure and of the high pressure engines. What can be more attractive than to combine them and follow the growth of the high-pressure condensing engine? By successive steps the student at length becomes acquainted, and thoroughly acquainted, with the essentials of steam engineering with no more effort than reading an entrancing history. What may be done with the steam engine may be done with other developments of inventions.

Let us now consider the history of technology from the biographical standpoint. Again we shall find that its educational value is great. The inspiration that springs from the study of famous men is felt by us all. Few have succeeded, but how many of us have desired, to do as they did, to conquer difficulties and leave behind us an ever-living name? There is a period in the lives of all young men when encouragement of the kind is needed; when they want stimulus of the larger vision to lift them out of the rut of monotony and routine into which their work has almost inevitably led them. Such a work as Oliver Lodge's *Pioneers of Science* may do much for them at this stage. In the study of biography their minds will be broadened by knowledge, their characters strengthened by example, and their ambition fired by the triumphant efforts of their great predecessors.

These two results, first education in facts and secondly education of character, are perhaps the greatest benefits to be derived from the history of technology, but there are others of a more definitely practical nature. Brief allusion has already

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been made to the importance of history in the administration of patents for invention. It is too obvious to need reiteration. In research work it is universally admitted that a complete review of all that has been previously accomplished is, or should be, the initial step in the opening of all new investigations. The history in such cases is not the precise kind of history with which this Society is concerned, and in the advancement of which Mr. Rhys Jenkins has set us a standard that none of us can hope to attain. But it is history nevertheless and it will lose nothing by that accuracy of details, dates and names which we can do much to encourage.

Finally, I think it is no small matter that a common love of the history of technology, without any ulterior motives, has brought us all together in our Society. I have no doubt at all that every one of us gains some tangible good by the contact with his fellow members and that the papers presented to us do more than interest and entertain us for a passing hour. In the contemplation of the development of industries and inventions our judgment is taught restraint, our imaginations are enlivened, and the moral influence which accompanies the doing of homage to those much greater than ourselves moves within us.

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Gentlemen, I have detained you long enough and must draw to a conclusion leaving my task half done. Perchance some future President may, with more skill and eloquence than I can command, return to this subject, this subject upon which our existence as a Society depends.

If I have succeeded in any degree in leading but one or two of you to take a large view of the work upon which we are engaged, to think of the history of technology as not merely interesting but of at least equal importance with the history of courts, kings, and conquests, I shall have achieved something. If, however, I should lead anyone in this room to consider if technology be not by far the most powerful factor in the development of civilisation, a factor far more important than all laws, save the moral laws, I shall have achieved more than I can dare to hope. Yet I am sure that it is only by a firm belief in the real value to the world of the work upon which the Newcomen Society is engaged we shall bring our little company to that destination for which we have laid our course. The future is before us; it hangs upon our endeavours, upon our constant faith that we are being of some service to our fellow men.

Departing from the usual practice on such occasions, the President said he would welcome any observations that Members might like to make on what he had said.

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DISCUSSION.

MR. T. E. LONES, in moving a vote of thanks to the Author, said the address was interesting and of intellectual value. He was pleased that the subject had been treated philosophically and that the Author had not insisted that there were material benefits resulting from historical studies; in fact the Author doubted if there were any. He personally considered the study of history, whether general history or the history of technology, to be of importance. History does repeat itself, not in details of course, but in the general sequence of events, and history, as old even as that of Thucydides, is of value in considering the general course of events in Europe during the past few years.

To come to history of technology it should, Mr. Lones thought, be conceded that it had value. What had we lost, for instance, through ignorance of the technical acquirements known to the ancients? There were many technical processes, *e.g.*, the manufacture of ultramarine, the secrets of which have been lost. It is probable that accounts of such processes were never recorded. In conclusion, he laid stress on, and exemplified the importance of keeping accurate records of engineering construction and technical processes.

MR. W. J. TENNANT, in seconding, congratulated the President and said he was greatly impressed by the address. It was a complete justification, if such were needed, of the Society's existence. It would open the eyes of engineers to the fact that there was other literature to be studied besides Molesworth.

The motion was carried by acclamation.

MR. H. W. DICKINSON said it would appear that the President had at the outset really believed or had intended to prove that there was value in technological history. Not only had he not established his thesis but he had really shown that the opposite was the case. He, the speaker, was glad of this rather than otherwise as he was one of those who looked upon the study of the history of technology as a recreation—a hobby if you like; it was the association or fellowship of like minds that attracted persons to the Society and induced them to join. He was glad that the President had pointed out that they had for their studies a very important aspect of man's activities and one that had an evolutionary aspect; this rendered it more valuable as an intellectual training than most of what had been studied hitherto under the name of history.

MR. RHYS JENKINS said he was relieved that the President had not taken up any dogmatic position—he had left the matter a very open one.

MR. L. A. LEGROS said that, like Mr. Lones, he had found difficulties in technical research. For instance, he found two different statements, each by authorities, as to the date of James Watt's death. As to keeping processes secret,

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he might instance the case of Bessemer's gold paint made from brass. The manufacture lasted longer than it would have done if patented and gave the inventor funds that enabled him to go on inventing and to bring out his celebrated steel process.

Mr. E. W. HULME said the President had given them as it were a philosophy for the Society. Its existence was a sign of the times, for in the last quarter of a century the study of history had been attracting men in increasing numbers, withdrawing their mental activities from old into new channels. No longer was everyone concentrating on obtaining a fruitful harvest from the physical sciences. More and more people were concentrating on man himself and anthropology which had been too much neglected in the past.

COLONEL W. H. D. CLARK said the address required no words of commendation from him. The President had raised the position of the study of technology to the level of that of history in general. Gathering facts and laying up information must be an essential part of their work—one that could be done by all of them. The address was a complete answer to anyone who doubted the value of the work the Society was doing and hoped that the address would be printed *in extenso*.

The PRESIDENT thanked the speakers for their indulgent remarks. He would admit that he had not made out a strong case as to the value of the work they were doing; he personally found that the work had a great charm and that was for him sufficient inducement and reward.

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The Dynamics of Leonardo da Vinci,

BY

Ivor B. Hart, O.B.E., Ph.D., B.Sc., A.F.R.Ae.S.

(Read at Caxton Hall, Westminster, December 6th, 1923.)

I. Introductory Note on the Manuscripts.

Leonardo da Vinci lived in the fifteenth and early sixteenth centuries (1452-1519). He was the natural son of Ser Piero da Vinci, a Florentine notary, and at the age of fourteen was apprenticed to Andrea Verrocchio, a famous artist of those days. Verrocchio's tastes, and as a consequence his circle of acquaintances, were wide, and from all these Leonardo imbibed and developed a passion for scientific inquiry side by side with his development as an artist. At Florence in his early days he came under the influence of such men of science as Benedetto del'Abbaco, Giovanni Agiropulo, L. B. Alberti and Toscanelli.

In 1483 Leonardo migrated to Milan, where he took service under Ludovico Sforza in the capacity of consulting engineer, architect and sculptor, and he was busily employed in all these capacities. His chief scientific friendship during this period was with Fra Luca Pacioli, the famous mathematician.

Leonardo's stay in Milan ended in 1499 with the collapse of the power of Ludovico Sforza, and for some years we find da Vinci back again at Florence. In 1506, however, he accepted an invitation from Louis XII of France to return to Milan. He remained there till 1512, and later, in 1515, Francis I. of France, Louis XII.'s successor, invited him to take up his residence in the Castle of St. Cloud, near Amboise. Here he spent the remainder of his days. He died on May 2nd, 1519.

The reading of Leonardo da Vinci's manuscript has been a task of enormous difficulty with which is honourably associated the names of a small band of enthusiastic students, chief among whom may be mentioned J. Paul-Richter, G. Piumati and C. Ravaisson-Mollien. Leonardo, from the time he was twenty years of age onwards, invariably wrote in a manner apparently calculated to confound his would-be readers. We may summarise the characteristics of his script under four heads. (1) He wrote from right to left after the fashion of the Semitic group of languages, (2) his handwriting was of the kind known as "mirrored," *i.e.*, reversed in a manner such as would be produced by looking

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at a normal script through a mirror, (3) he employed an elaborate scheme of abbreviations, and (4) he omitted the use of punctuation. It is accordingly much to the credit of the patient workers to whom reference has been made above that in spite of these difficulties the writings of this great genius of the Italian Renaissance have been rendered available to the world of science and letters generally.

It is only within comparatively recent times that the vast collection of notes and sketches accumulated by Leonardo da Vinci has been given the attention it deserves. Unfortunately circumstances were such that after his death they were lost sight of, and it was only after the lapse of centuries that they once again came to light. This loss was a serious misfortune to science of a very high order. Leonardo's work was in itself so fruitful and varied, and his outlook on nature was so vastly superior to that of those about him, that if only those who followed after him could have had access to his writings and to his many anticipations of later discoveries in various fields of intellectual activity there is no doubt that the course of scientific history would have been materially different in a number of vital directions.

It is not intended in this introductory note to give a history of the vicissitudes of the manuscripts. It will, therefore, suffice for us to note briefly that the tragical dispersal of the note-books began about the year 1570 (on the death of Melzi, the guardian to whom they had been bequeathed by da Vinci fifty years previously). They were practically lost to the world of learning for some 200 years, by which time the bulk of those which still existed were acquired by the Ambrosian Library at Milan, and comprised (*a*) one very large and heterogeneous collection bound into a volume known as the Codex Atlanticus, and (*b*) twelve other volumes of notes. These latter were commandeered by Napoleon in 1796, and were transferred by his orders to the Institute of France in Paris, where they have remained ever since.

Here the volumes were carefully examined by Venturi and to him the world is indebted for the first real description of the manuscripts.[1] For purposes of reference, Venturi assigned to each manuscript a capital letter beginning with A, and this designation has since received general acceptance.

In spite of the 125 years which have elapsed since Venturi's book was first published, it may justly be said that the detailed study of Leonardo's contributions to science is very incomplete, and it must definitely be admitted that in this respect the scientific historians of this country have been somewhat neglectful. Beyond a recent translation into English of the Manuscript on the Flight of

[1] J. B Venturi, "Essai sur les ouvrages physico-mathématiques de Leonardo da Vinci," Paris, 1796.

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Birds'[2], translations of Leonardo's note-books are only to be found in French[3] and modern Italian[4], whilst commentators on these books have hitherto been largely confined to French and German philosophers. A survey in English of the whole subject is therefore very much to be desired.

II. Factors in the Criticism of da Vinci's Note Books.

It is proposed in this paper to consider the various contributions by Leonardo da Vinci in the field of dynamics—a study to which he referred as the "paradise of the mathematical sciences."[5] His notes in this subject are found scattered throughout his writings with a frequency and a persistence which show clearly the importance which he attached to it. They have at various times been considered by a number of students—notably by Grothe,[6] and Schuster[7] (and more superficially by Seailles[8]) in the realms of theoretical mechanics, and by Feldhaus[9] in the study of Leonardo's applications of mechanical principles to mechanisms.

By virtue of the nature of the note-books, and of the circumstances under which they were compiled, there is always of course the danger of reading into da Vinci's notes and sketches an ordered and a systematic scheme of mechanics which, if would be easy to argue, did not in fact exist in his mind. Nevertheless, the constant repetitions in various forms of important statements and experiments do speak for themselves with a definiteness which must not be denied, and to this we must add the plea that the final judgment of a philosopher must depend not only upon his casual notes, jotted down at various odd moments, but upon the connected writings derived from those notes. We have already pointed out that Leonardo intended to reach this stage, but never in fact did so, and as a consequence we are entitled in common fairness to collate his materials, and to set them forth in such a manner as would enable us to estimate their intrinsic value, both in the light of the contemporary knowledge of his own days, and of those which followed in the normal course of the historical development of mechanics.

At the outset it may be stated frankly that Leonardo suffered badly from the want of a precise and an accurate scientific vocabulary. All the modern ideas of force, motion, mass, inertia, work, moment, etc., are constantly to be found amongst the notebooks of our philosopher; but they are cloaked in a phraseology

[2] I. B. Hart, "Leonardo's manuscript on the Flight of Birds," Journal of the Royal Aeronautical Society, June, 1923. This has been incorporated in the Author's "The Mechanical Investigations of Leonardo da Vinci," 1925.

[3] M. Charles Ravaisson-Mollien, "Les Manuscrits de Leonardo da Vinci—Les Manuscrits de la Bibliothèque de l'Institut de France," Paris, 1883-1893.

[4] Piumati, "Il Codice Atlantico di Leonardo da Vinci nella Bibliotheca Ambrosiana di Milano."

[5] MS. E., Fol. 8v.

[6] H. Grothe, "Leonardo da Vinci als Ingenieur und Philosoph," Berlin, 1874.

[7] F. Schuster, "Zur Mechanik Leonardo da Vincis," Erlangen, 1910.

[8] G. Seailles, "Léonard de Vinci, l'Artiste et le Savant," Paris, 1906.

[9] F. M. Feldhaus "Leonardo da Vinci als Techniker und Erfinder," Jena, 1913.

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which is rarely precise, which is frequently puzzling, and which is seldom rigid. Yet condemnation for this would surely be most unjust. The notion of rigidity in scientific thought had no place in the fifteenth century. Looseness of expression is frequently the result of ignorance. A wealth of such looseness is not an unknown device as a cloak of assumed wisdom to hide such ignorance—a pseudo-learnedness, as it were. This was a device typical of the encyclopaedists of the Dark Ages, many of whom developed an extraordinary facility for writing page after page of nonsense round a single and frequently unimportant point. None, however, can accuse Leonardo da Vinci of belonging to this class of writer. There is, however, the other side of the picture—the looseness of expression due to a sheer inadequacy of words to convey new ideas such as may occur to a writer who lives ahead of his times. It is to this side of the picture that Leonardo belongs. Many of his ideas,— lost with the dispersal of his manuscripts, had to be rediscovered by others long after him. That those later philosophers had the benefit of a later and a more complete terminology with which to state their discoveries is a fact that need neither detract from the credit due to Leonardo nor blind us to the difficult path of inadequate language through which he had to grope his way.

Yet another factor requires mention in this connection. Clarity of thought in the exact sciences could not properly come into its own until the test of experiment had been recognised and practised. It is a commonplace in the history of science that little real headway was made until the advent of such pioneers of experimental science as Galileo in Italy and Gilbert in England. These preachers, by inaugurating a new era in scientific research, heralded the downfall of the dogmatists, and paved the way for such an advance in accurate scientific knowledge as to render absolutely imperative an expansion of technical vocabulary.

Now Leonardo, more than one hundred years before Galileo, was most definitely an experimentalist. If the great Tuscan philosopher was indeed the "Father of the Experimental Philosophy," then da Vinci was its grandfather. "Experience (i.e. experiment)," says he, "never deceives; it is only our judgement which deceives us, promising from it the things which are not in its power."[10] The appeal to experiment pervades all his writings on scientific topics. Small wonder, therefore, that his ideas and his discoveries outstripped his language. Living and thinking in terms of the late sixteenth and seventeenth centuries, he was yet compelled to express himself in the restricted language of the fifteenth. Vagueness of expression in the circumstances was inevitable. For these reasons, therefore, it behoves us to approach the notes on mechanics in no hypercritical spirit, but to make due allowances by assuming for ourselves rather the rôle of the "man in the street," to whom ideas of scientific rigidity are foreign and are replaced by what he would call the "common sense of it."

[10] Codex Atlan, Fol. 154r. See also Fols. 3r and 119r.

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III. Da Vinci's Dynamics.

Force and the Principle of Inertia.—Immediate examples of the vagueness of language, but not necessarily of thought, occur in the various references contained in Leonardo's manuscript to the term " force." Mechanics being in effect the study of rest and motion, da Vinci was quite clear as to the fundamental importance of this concept of force. " Nothing whatever can be moved by itself," he tells us,[11] " but its motion is effected through another. This other is the Force." We have here at one and the same time his conception of the term force, and of what we speak of to-day as the principle of inertia. It is by no means the only example. Thus, in his endeavour to bring out the non-material nature of force, he writes,[12] " Force I define as a spiritual power, incorporeal and invisible, which with brief life is produced in those bodies which as a result of accidental violence are brought out of their natural state and condition. I have said spiritual because in this force there is an active, incorporeal life; and I call it invisible because the body in which it is created does not increase in weight or size; and of brief duration because it desires perpetually to subdue its cause, and when it is subdued it kills itself." This passage contains, of course, much that is nonsense so far as the standards of to-day go, but the scientific spirit is there. His analysis of what he regarded as the three " properties " of force, spirituality, invisibility and brevity of duration, and his common-sense deduction as to the invariability of the " weight " (i.e. of the mass) of a body before, during, and after the action of the force, are of a standard far beyond his days.

We have already mentioned the implication of the principle of inertia in Leonardo's understanding of the term force. He says that a body which is at rest cannot move of itself. It is important to note that he extended this to the case of the inertia of a moving body. Thus, in his manuscript " On the Flight of Birds," in the course of a discussion on the sudden turning of a bird on to its side, he says, " And because all movement tends to maintenance, or rather, all moved bodies continue to move as long as the impression of the force of their motors remains in them."[13] Here, surely, we have a real flash of the scientific genius which forestalled Galileo (to whom the credit of the first enunciation of the Principle of Inertia is generally ascribed) by more than a hundred years. One can almost read in the above phraseology the classic First Law of Motion of the illustrious Newton as it is taught to-day in schools.

The Law of Reactions.—The first was not the only one of the famous " Three Laws " which da Vinci either tacitly assumed or actually enunciated, although not, of course, in the precise or definite manner of his successors. It may reason-

[11] MS. A, Fol. 21v.
[12] MS. B, Fol. 13r.
[13] Sul Volo degli Uccelli, Fol. 13(12)r.

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ably be claimed that in its crudest sense—namely, that the effect of a force is proportional to the magnitude of the force acting—the Second Law of Motion is more or less implied in da Vinci's notes as an instinctive truism.

The Law of Reactions, however, certainly does find a definite place in the manuscripts. Thus, in the Codex Atlanticus, in the course of a note on the parachute, we read, " An object offers as much resistance to the air as the air does to the object.[14] Although the statement here takes the form of a particular application, it is clearly of a character which leaves little doubt as to the writer's definite appreciation of a general law of reactions. A similar reference is to be found later in the same manuscript.[15]

Force and Motion.—Turning to the relationship between force and motion, it is to be noted that da Vinci, following the teachings of Aristotle,[16] laid down a series of enunciations in this connection,[17] a reference to which will show that in effect he regards the intensity of a mechanical action (i.e. of a force) to be proportional to the velocity which it communicates to a mobile body. He had not reached the stage of realising that it was the *acceleration* which was in question, and not the velocity. As an example of this, let us test in the light of modern elementary dynamics the second of Leonardo's enunciations. Thus, he says that " if a force moves a body in a given time over a given distance, the same force will move half this mass through the same distance in half the time." Using the formula $F=Ma$, and denoting by a_1 the acceleration produced when the mass reduces to $\frac{M}{2}$, we have,

$$(1)\ F=Ma, \text{ giving } a=\frac{F}{M}, \text{ and } (2)\ F=\frac{Ma_1}{2}, \text{ giving } a_1=\frac{2F}{M}, \text{ whence } a_1=2a.$$

Next let s be the distance through which the mass moves, mass M in time t and mass $\frac{M}{2}=M_1$ in time t_1.

$$\text{Now } s=\tfrac{1}{2}at^2, \text{ giving } t^2=\frac{2s}{a}. \quad \text{Also } s=\tfrac{1}{2}a_1t_1^2=\tfrac{1}{2}.2\,a\,t_1^2, \text{ giving } t_1^2=\frac{s}{a}.$$

$$\text{Hence } \frac{t^2}{t_1^2}=\frac{2}{1}, \text{ giving } \frac{t}{t_1}=\frac{\sqrt{2}}{1}, \text{ and not } \frac{2}{1} \text{ as stated by Leonardo.}$$

Falling Bodies.—Here again our philosopher just fell short of the realisation of an important truism which might otherwise have carried him very far. However, throughout all his scattered notes on this subject,

[14] Codex Atlan., Fol. 372b.
[15] Codex Atlan., Fol. 115rb.
[16] Mechanica Problematica.
[17] MS. F, Fol. 26r, Fol. 51v.

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Leonardo the experimentalist stands out very clear.[18] "If a weight of a hundred pounds falls ten times from the height of ten fathoms on one spot, and sinks in one fathom, how much would it sink in falling from the height of one hundred fathoms?" is a typical query.

In another manuscript we read as follows: "Why does not the weight O remain in its place? It does not remain because it has no resistance. Where will it move to? It will move towards the centre [of the earth]. And why by no other line? Because a weight which has no support falls by the shortest road to the lowest point, which is the centre of the world. And why does the weight know how to find it by so short a line? Because it is not independent, and does not move about in various directions." Here then we get Leonardo's philosophy of the falling body in a nutshell, so to speak. It was his study experimentally of bodies falling freely under the action of their own weight which led him to the idea of a uniformly accelerated motion. A note in Manuscript M is very significant. "In the air of uniform density, the heavy body which falls at each stage of time, acquires a degree of movement more than the degree (of movement) of preceding time."[19] Here the idea of an acceleration is very clearly brought out. Later in the same manuscript we read, "If after the descent of a fathom by one ball you let fall another, you will find that at each stage of the fall the proportion of their velocities and powers will change."[20] Interestingly enough, in the same manuscript another passage[21] makes it quite clear that da Vinci was aware of the influence of the resistance of the air. He discusses the fall of two equal weights, the one vertically above the other, and notes that the distance between them steadily diminishes as they fall, until the bodies touch, his explanation being that owing to the screening effect of the lower body upon the upper one, the resistance of the air retards the motion of the former, but not of the latter.

Leonardo da Vinci definitely sought to discover the true law of accelerations for falling bodies. In one note, for example, he enunciates his problem thus:—"If a weight falls a distance of two hundred fathoms, by how much would it fall quicker in the second hundred fathoms than in the first?"[22] Unfortunately he failed to find a correct solution to his question. The correct law for falling bodies is, of course, that the fall is proportional to the square of the time, but Leonardo concluded that the function was linear. In Manuscript M we find the following passage, a portion of which has already been quoted above:—"In the air of uniform density, the heavy body which falls at each stage of time, acquires a degree

[18] MS. A, Fol. 3r.
[19] MS M., Fol. 44v.
[20] MS M., Fol. 61r.
[21] MS. M., Fol. 43v.
[22] MS. A., Fol. 3v.
[23] MS. M., Fol. 44v.

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of movement more than the degree (of movement) of the preceding time, and likewise a degree of velocity more than the degree (of velocity) of the preceding time. *Then to each quantity doubled in time, the length of the descent is doubled, likewise the velocity of the movement.*[23] We see from the sentence in italics that da Vinci regards (I) the velocity as proportional to the time which is correct (c.f. the formula in kinematics, $v=gt$), and (II), the height of fall is also proportional to the time, which is incorrect. Additional interest is lent to the above passage by a sort of graphical representation of a velocity-time scheme adjoining it, with a time scale shown horizontally, and a velocity scale vertically, somewhat as follows:

```
1   2   3   4   5   6   7   8   9   10
o   o   o   o   o   o   o   o   o   o
o   *   *   *   *   *   *   *   *   *
    o   *   *   *   *   *   *   *   *
        o   *   *   *   *   *   *   *
            o   *   *   *   *   *   *
                o   *   *   *   *   *
                    o   *   *   *   *
                        o   *   *   *
                            o   *   *
                                o   *
                                    o
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The note against this scheme reads thus:—" Here is shown how such a proportion as one quantity of time with another, will have a quantity of movement with the other, and a quantity of speed with the other." From some points of view it may fairly be claimed that this was the earliest example of the graphical method in the history of the mathematical sciences, and as such it calls for our respectful admiration.

Influence of the Earth's Rotation on Falling Bodies.—In the course of his investigations on the falling of heavy weights Leonardo shows us a very brilliant example of sound scientific deduction. He dropped a number of heavy weights from the top of a tower, and noticed that they did not meet the ground absolutely vertically beneath the starting point. There was, he thought, a small easterly deviation, and this he proceeded to explain by its true cause, namely, the rotation of the earth on its axis. Actually, is seems impossible that in the relatively small fall of a body from the top of a tower, such a deviation is capable of observation. The probability is that Leonardo *thought* he saw it, and was thus started on a train of thought which led him to conceive why there *must* be such a deviation so that it would never afterwards occur to him to doubt the accuracy of his observations. The passage in question occurs in Manuscript C of the collection at

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the Institute of France, and is illustrated by a diagram similar to Fig. 1. "Let *a* be the body," says Leonardo in his note,[24] "which falls from the highest part of the sphere of fire[25] in order to come to the mid-point of the earth *m*. I say that this

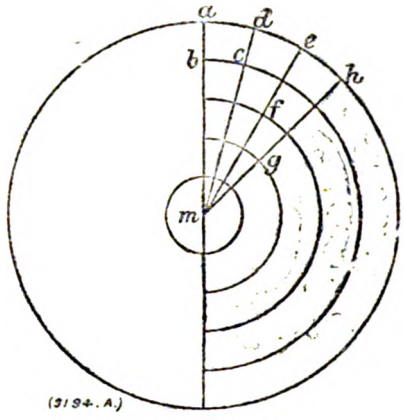

FIG. 1.

weight descending in spiral will not leave the straight line which follows its way towards the mid-point of the earth. Because if the body goes from *a* in order to reach *b*, so will it go towards *b* and come to the position *c*. The point *a* in turning reaches *d*. If one now considers the position of the body, one finds that it is always found in the straight line which originally at *a* and now at *d*, joins it to the mid-point of the earth at *m*. If the body goes further towards *f* then will the point *d* at the same time go to *e*. During the descent from *f* towards *g*, the rotation of *e* is brought into the position of *h*. So the body descends to the earth, always out of the starting point. This is an accumulative movement. It is a combination of a straight line and a curved line. It is a straight line because the body is always found on the shortest line which joins it from *a* to the centre of the earth. It is a curved line in itself and in every point of the path. Therefore a stone thrown from the height of a tower does not strike the wall of the tower until it reaches the earth."

The Compounding of Forces and Velocities.—A point of immediate importance in connection with the preceding note is that we are here afforded a definite example in Leonardo's manuscripts of the virtual compounding of two velocities or

[24] MS. G., Fol. 54v and 55r.

[25] It should be remembered that the mediæval conception of the universe was that of the firmament around the *globus mundi* being surrounded by "elemental" spheres (moving successively outwards) of water, air, and fire, and beyond these the planetary spheres, then the sphere of the fixed stars, and finally the *primum mobile*.

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motions into a resultant single motion different from either of the constituent ones. Seailles[26] even goes so far as to regard it as an appreciation by Leonardo of the principle of the physical independence of forces and velocities, but this is perhaps straining the point beyond the stage of justification. The question, however, of whether or no we may fairly say of da Vinci that he knew that of which to-day we speak as the principle of the parallelogram of forces and of velocities is full of both interest and importance. Probably it is most true to say that he knew *something* of this principle—that he was in fact on the fringe of its discovery. Duhem definitely takes the opposite view,[27] and in support of this he quotes a passage which is accompanied in the manuscript by the diagram shown in Fig. 2, and which

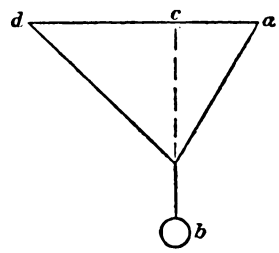

FIG. 2.

reads as follows: "The suspended weight at the angle will divide its weight between the two sides of the angle in the same proportion as that of the obliquity of their sides. Or, such a weight will distribute itself between its supports in the same proportion as that of the two angles formed of the division of the angle where the weight is suspended. . . . Thus the angle *abd* being cut by the line *eb* and the angle *edb* being 9/11 of the angle *abc*, the angle *abc* is 2/11, *ab* is the 9/11 of the weight, and *db* 2/11." This of course is a faulty conclusion, but it does not follow that it is not due to faulty mathematics rather than to faulty mechanics. After all, judging by their absence from his note-books, Leonardo was probably none too happy with his trigonometrical ratios. But quite apart from any such considerations, we can hardly expect such a problem as the above, essentially one on the tensions produced in the two strings by the hanging weights, to be regarded by anybody in the fifteenth century, however brilliant, as an example of the combining of two forces into a single equivalent resultant. It is fundamentally either a deduction from the *converse* of the principle of the parallelogram of forces (to which we will refer in the next paragraph), or it may be looked upon as a specific case of the principle of the triangle of forces. We are bound to say,

[26] G. Seailles, "Léonard de Vinci, l'Artiste et le Savant," Paris, 1905, p. 229.
[27] P. Duhem, "Les Origines de la Statique," Paris, 1903.

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therefore, that quite apart from whether Duhem was right or wrong in his conclusion, the example he quotes in support of his contention is scarcely admissible.

It is in fact rather difficult to find a definite example in which da Vinci is led to enquire into the effect of two forces acting simultaneously on a body. In the manuscript "On the Flight of Birds," however, he does mention one such note,[28] the forces in question being the weight of a bird and the force of the wind, and although Leonardo neither constructs nor mentions a parallelogram, he at least definitely speaks of a resultant effect—he mixes his forces and his velocities quite freely—intermediate between the two. The passage reads as follows:—"(Falling.) The bird being in the act of falling in the direction of its open wings (Fig. 3) with a force of 4 and the wind which strikes it underneath with

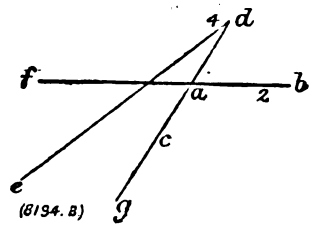

FIG. 3.

a force of 2 makes its course straight; we will say then that the descent of such a bird will be by the mean line between the level of the course of the wind and the obliquity in which the bird was with the force 4. As: let the obliquity of such bird be the line *abc*, and let the wind be *ba;* I say, if the bird *abc* had a force 4 and the wind *ba* had a force 2 that the bird would not go in the direction of the wind (either) in *f* nor by its obliquity in *g* but would fall by the mean line *ae;* and one proves it thus."

The Resolution of Forces.—But what of the converse problem—that of the resolution of a single force or velocity into two components? References in Manuscript G are most illuminating in this connection. In the course of a discussion on the motion of a weight sliding down an inclined plane, we read, "The weight which descends obliquely divides its weight in two different aspects. One proves it thus: Let *ab* (Fig. 4) move according to the obliquity *abc*. I say that the weight of the body *ab* divides its gravity in two aspects, that is, according to the line *bc* and according to the line *mn*. Why and how much the weight

[28] "Sul Volo degli Uccelli," Fol. 6(5)r.

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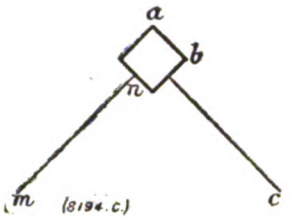

FIG. 4.

is greater for one than for the other aspect, and what obliquity is that which divides the two weights in equal parts, would be in the weight of the body?"[29]

Motion down an inclined plane.—It will be convenient more generally to consider at this stage the way in which Leonardo da Vinci dealt with the problem of the motion of a body down an inclined plane, a subject not attempted by any of his predecessors. He first considers a sphere on a horizontal plane, and points out that the perpendicular through the centre of gravity passes through the point of contact, there being no resulting motion. He next passes on to a sphere on an inclined plane, and shows that the vertical line through the centre of gravity lies on one side of the point of contact, and the body is driven down the plane by the action of a force. Leonardo realises that as the angle of inclination of the plane increases, so do both the distance between the point of contact and the vertical line through the centre of gravity (*i.e.*, the distance *om* in Fig. 5), and the speed of

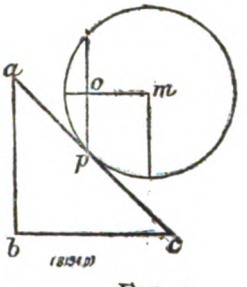

FIG. 5.

movement of the sphere down the plane. He assumes (presumably from general observation) that this speed of movement is proportional to *om*. "The greater is the distance between *m* and *p*," he writes,[30] "the greater will be its speed." It would not of course be correct to speak of this motion down the plane as a "velocity," since in fact the motion is accelerated. So keen an observer as

[29] MS. G., Fol. 75v and 76r.
[30] MS. A., Fol. 52r.

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Leonardo will naturally have realised this fully, and as is seen from a further passage, he uses the term " rapidity of movement." Leonardo's conclusion may be given in his own words. " The spherical body (Fig. 5) will take up a movement which is more rapid as its contact with the point where it runs will be more distant from the perpendicular from the central line. As much as *ab* is less than *ac*, so much will the spherical body fall more slowly down the line *ac*."[31] It is probable that da Vinci, in the phrase " much as *ab* is less than *ac*," had not in his mind the idea of a difference. It is more likely he was thinking of the *ratio* of *ab* to *ac*.

The Principle of Work. — We next turn to a consideration of Leonardo's writings regarding that of which we speak nowadays as the " principle of virtual velocities." It need scarcely be said at the outset that da Vinci never made use of the term " work " in the modern technical sense. Nor did he have any clear ideas as to the importance of the product of force and distance. Nevertheless he did appreciate the fact of a value in, and a measure of, what we might speak of as the *achievement* of a force. In Manuscript F, for example, we find a series of enunciations regarding forces, the last of which reads as follows:— " If a force carries a weight in a certain time through a definite distance, the same force will carry half the body in the same time through double the path."[32] There are other pronouncements in the same strain. They contain the germs—and indeed the live and very healthy germs—of the present-day principle of work, or the principle of virtual velocities. There is, in effect, a definite limit to the results of a given effort, and this effort is not alone a question of the magnitude of the force, but also of the distance, in any given time, through which it acts. If the one be increased, it can only be at the expense of the other.

Again, in the Codex Atlanticus, in the course of a note on the use of a machine for the movement of heavy bodies, Leonardo writes, " When the moving part exerts more movement in the same time than the moved body, then it (*i.e.*, the power) has more force than the moving body, and it will move more quickly than the body itself. When the part which is the moving part has less speed than the moved part, then it will have the less force than the moved body."[33] Again we see the contention, in effect, that the forces which are in equilibrium in a machine are in inverse proportion to their virtual velocities.

There is to be found in Manuscript E a beautifully clear application of this, albeit typical of many others, in what is really a discussion on the mechanical advantage of a pulley system, illustrated in the note by a sketch (Fig. 6). " The powers," writes Leonardo, " that the cords interposed between the pulleys receive

[31] Ibid.
[32] MS. F., Fol. 51v.
[33] Codex Atlan., Fol. 185r.

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from their movement are between them in the same proportion as are between the speeds of their movements. The movements made by the cords on their pulleys, the movement of the last cord is in the same proportion with the first as that of the number of the cords; that is to say, that if there are five, the first cord moving one yard, the last will move a fifth of a yard; and if there are six, this last cord would have movement of one-sixth of a yard, and so on to infinity.

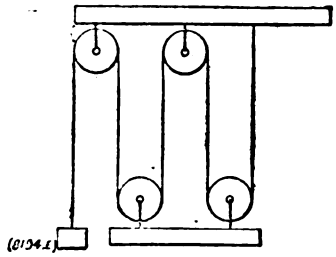

FIG. 6.

The proportion which the movement of the force of the pulleys will have with the movement of the weights raised by the pulleys will be such as that of the weights raised by these pulleys with the weight of the force."[34]

Perpetual Motion.—Intimately linked up with this principle of work is the age-old myth of perpetual motion. If the principle of work be true, then the achievement of perpetual motion is impossible. On this matter Leonardo had no illusions whatever. There were, however, many contemporary with him, vain ancestors of our present-day would-be inventors of the perpetual-motion machine, who thought otherwise, and with these da Vinci had no patience. "Oh speculators on perpetual motion," he writes, "how many vain projects of the like character you have created? Go and be the companions of the searchers after gold."[35]

Leonardo understood clearly the limitations implied by the principle of work. "No inanimate object," he says, "will move of its own accord; consequently when in motion it will be moved by unequal power, unequal that is in time and velocity, or unequal in weight; and when the impulse of the first motive power ceases, the second will cease abruptly."[36] In other words, a given expenditure of power produces only a finite result, and if further results are required, then a further expenditure of power is necessary. Later in the same manuscript we find a practical illustration of this, in a note on the water-wheel. "If a wheel is moved for a moment by a quantity of water, and if this water is not added to either

[34] MS. E., Fol. 20r.
[35] MS. S.K.ii2, Fol. 67a.
[36] MS. A., Fol. v.

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by flowing or by quantity, or by a greater fall, the function of this water is finished."[37]

With such lucid conceptions, we need scarcely be surprised, therefore, that Leonardo da Vinci writes " Satanasso " against "perpetual-motion " comments in his notes, and that he consigns the " perpetual-motion " dreamers with a gesture to their true place among the ranks of the large army of necromancers, searchers after the philosopher's stone, and the other quacks of those times.

Impulsive Forces.—We conclude with a brief comment upon Leonardo's notes on the subject of impulsive forces. That he realised that these forces of percussion, as he called them, were at all different from forces in general is a fact which in itself calls for our appreciation; but there was certainly something more in his understanding of this class of forces than the bald fact of their existence. It is clear from his references in the Codex Atlanticus[38] and elsewhere that he carried out a number of experiments both on the collision of bodies, and upon the recoil of spherical bodies from plane surfaces. His two chief conclusions are on the subject of the glancing impact of smooth spherical bodies on smooth planes. The first is that a blow applied normally to a surface has a greater effect on the plane than one applied at an angle, and that of two such inclined blows, the one whose angle of incidence is the smaller produces the great effect. " The blow," he writes, " will be less powerful than its impulse according as the angle of its percussion is nearer the right-angle."[39] The second conclusion is that for a rebounding body, the angle of incidence is equal to the angle of rebound. This is embedded in a note headed " Percussion," which reads as follows:— " The line of percussion (incidence) and that of rebound (reflection) are placed at the middle of equal angles. All blows struck on an object rebound by an angle equal to that of the percussion. This proposition appears clearly; in effect, if you strike a wall with a sphere, it will rebound behind by an angle equal to that of the percussion. Thus if the ball *b* (Fig. 7) is thrown on *c*, it will return by the line

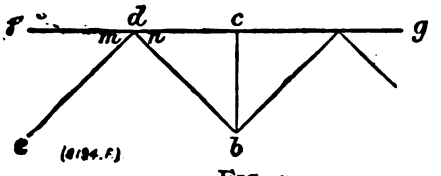

FIG. 7.

cb, because it is constrained to fall on the wall *fg* at equal angles (*i.e.*, normally); and if you throw it by the line *bd*, it will return back by the line *de*, and thus the

[37] MS. A., Fol. 30r.
[38] Codex Atlan., Fols. 28, 47, 64, &c.
[39] MS. A., Fol. Iv.

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line of percussion (incidence) and the line of rebound make an angle on the wall *fg* situated at the middle of two equal angles, as one sees the angle *d* between the angles *m* and *n*."[40]

Conclusion.—We have thus passed in review the chief contributions of Leonardo da Vinci to one of the two main branches of the science of mechanics. It is a fact that the field of Statics claimed even a larger share of his attention. Nevertheless it must be remembered that whereas up to the time of Leonardo the history of mechanics was virtually a history of statics, the study of bodies in motion was almost entirely a new one. In this respect, as in so many others, our philosopher was a true pioneer. Dynamics had made such very little headway since the Greek days of speculation on theories of gravity chiefly because the influence of the Peripaticians was persistently against experiment—a situation with a distinct element of irony in view of the fact that their great master, Aristotle, was himself so keen an observer of nature. From this attitude, as we have seen, Leonardo broke completely away. Paying due respect to the wisdom of the ancients, who indeed influenced his views very profoundly, he yet maintained the claims of the test of experiment. Naturally a genius, professionally an artist and an engineer, he was bound to break new ground. To those who, surveying the subject-matter of the previous pages of this paper, are tempted to regard the dynamics of Leonardo as superficial and bare, we would answer that the wonder is not that he did so little, but that he accomplished so much. For of the whole it may justly be said that it constituted pure research in a virgin field.

Dr. Hart said he would not formally read his paper as abstract copies were in the hands of Members but proceeded to give a discourse on da Vinci, illustrated by lantern slides, of a more general character than that in the paper, and the

Discussion

turned mostly on the points thus raised.

The President, in moving a vote of thanks to the Author, said that they had really to thank him for two papers instead of one. He would like to know the date when the Codex was compiled.

The vote of thanks was carried by acclamation.

Colonel Belaiew confessed to a great admiration for da Vinci. He commented on his method of reversed writing and said that he did this probably to save himself from ill consequences. The speaker instanced the case of Bransky, a disciple of Kant, in the time of Alexander I. of Russia, who wrote in an exactly

[40] MS. A., Fol. 19r.

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similar way and whose writing was only deciphered some 10 or 15 years after his death. His writing covered the whole field of mathematics, and when his works were published—*Technia*—in the early 19th century, Laplace and others burnt the book and would have consigned the author to an asylum. If it was unsafe for Bransky, it was many more times unsafe for da Vinci. There may also have been the intention to attract people fond of solving mysteries.

Mr. T. E. LONES classed da Vinci with Aristotle and Roger Bacon in outstanding eminence in science. If he had to state whether da Vinci's phraseology was always consistent, he would at once admit that it was not, but he was no wise singular in this as it would be found to be the case with other workers in science. Besides we have here a man much before his time and it was unfair to judge him by later standards.

Mr. G. F. ZIMMER commended da Vinci's clearness on the subject of perpetual motion upon which so many writers were then wasting their time. In the Codex Atlanticus, he criticises these persons as blockheads and churls. In another place he mentions having gloated over many worthless plans in this research.

Mr. THOMAS CLARKSON confessed to having been fascinated by the lecture. It was staggering to realise the conception da Vinci had of mechanical principles.

Mr. JENKINS, Mr. TITLEY, Mr. SIEVEKING and COMM. ROBERTSON also took part in the discussion.

Dr. HART, in reply, said that the whole difficulty with da Vinci was that of estimating the value of the different parts of his writings and what he really meant. It must always be remembered that we only had his notes and it was unfair to judge any man by those. Had he lived, we should doubtless have had something ordered, digested, and intelligible; in other words, a treatise, or rather a series of treatises on mechanical subjects. As to his consistency we must remember that he had a scientific mind and therefore was open to conviction or to change of view; we do not find notes crossed out and marked as false. On the whole, we find a large measure of consistency. If one examined the writings of the alchemists of the time, one would see how obscure, unintelligible and bombastic they could be; compared with them da Vinci was perspicuity itself. As to the date when the notes were compiled, all that could be said was that the compilation ranged over a number of years, probably from 1490 onwards. As to his left-hand writing, it is probable that he was born left-handed and that his father must have tried to suppress this inclination, because normally he wrote right-handed, but it came out, for example, in the fact that his shading is left-handed. The theory that he wrote left-handed in order to prevent plagiarism by others is really unnecessary—it was the natural thing for him to do.

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Mr. L. A. LEGROS wrote that he had been struck by some remarks in a work on da Vinci,[41] that were so pertinent to the work of the Society that he felt he must quote them:—

> " L'on reproche à notre siècle de trop regarder en arrière toutes les fois qu'il s'agit d'art; ne serait-on pas plutôt dans le vrai en constatant qu'en matière de science, il n'a pas suffisamment souci du passé! A peine si l'oeuvre des grands inventeurs tente de loin en loin la curiosité de quelque chercheur; nous en sommes réduits aux vulgarisations si hâtives—pour ne pas dire plus—de Louis Figuier, là où il faudrait l'intervention d'hommes du métier. L'un de ceux-ci—M. Berthelot—a cependant montré, en ces toutes dernières années (et avec quelle supériorité!) que les études rétrospectives ne nuisent nullement à l'originalité et qu'il est facile de rendre justice aux efforts de devanciers, tout en frayant à la science des voies nouvelles. Ce ne sera pas une des moines fécondes leçons que nous aura données l'illustre historien de l'alchimie."

[41] Eugène Müntz, Léonard de Vinci, 1899, p. 305.

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The Chain-of-Pots in the Sixth to the Seventh Century,

By G. F. Zimmer, A.M. Inst. C.E.

(Read at Prince Henry's Room, Fleet Street, February 6th, 1924.)

When I had the pleasure of presenting the paper entitled "The Early History of Mechanical Handling Devices,"[1] before this Society I was unable, in spite of much research, to assign a definite date for the early use of the chain-of-pots, the progenitor of the modern bucket elevator, beyond stating that it was probably used for watering the hanging gardens of Semiramis. Quite recently I came across some information which, although not fixing a very early date, shows that the chain-of-pots was in use at any rate in the sixth and seventh century of our era.

This information is gleaned from a Coptic papyrus of the sixth to the seventh century A.D. in the possession of the University of Bâle. The papyrus was executed at Hermapolis and is in excellent condition. It was translated by W. Spiegelberg of Strassburg, who began the task in 1912 and completed it in 1914 with the assistance of O. Eger of Bâle, W. E. Crum and Friedrich Preisigke.[2] The papyrus is a memorandum of Agreement for the Hire of a Chain-of-Pots, and its literal translation is as follows:—

> I, Papostolos, son of Serapion, whose mother's name is Anna, of Nagos in the Province of the City of Schmun (Hermapolis), write to the Scribe, Phoibammon, son of the late Georgios of Schmun. Behold, there is a great water-wheel (Sakia) having 40 blocks with the pots appertaining thereto. This same have I hired from thee, and I undertake to deliver to and for thee 19 measures of wheat, standard measure. These do I undertake to deliver unto thee, so God will, from the harvest of the third Indiction, in the month Epiphi. When the irrigation is finished I undertake to return the wheel to its original place in the same condition as when we took it over, provided that

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[1] *Transactions*, Vol. II., 1.

[2] "Abhandlungen der König. Gesell, der Wissenschaften an Göttingen."—Phil.-Hist. Klasse, Neue Folge, Band XVI., No. 3.

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if we fail to return it, or if it has been taken away from us, I undertake to deliver to and for thee 27 Keratien, without recourse to law and without the slightest doubt.

I, PAPOSTOLOS, Son of Serapion, approve this agreement.

(Second Signature, in Greek) written on 28 Phoephi of the Second Indiction.

(Third Signature, in Greek) ANUTHIS, Son of Victor the Deacon, witness the Document.

(Fourth Signature, in Greek) written, with the help of God, by me, VICTOR, the writer of the Agreement.

(Endorsement in Greek.)

PAPOSTOLOS, Son of Serapion, of the Village of Nagos in the Province of Hermapolis.

Unlike the chain pumps of China, which were mostly portable, the chain-of-pots is a cumbersome, stationary, timber structure, composed largely of palm stems. The contract between Papostolos and Phoibammon was for the hire of the endless double rope with 40 wooden blocks or distance pieces and the 40 earthenware pots attached to it, for which the payment of the 19 measures of wheat was to be made in the month of Epiphi, nine months later. This suggests that the pitch of the pots in the endless chain was of a standardised dimension, so that it could be removed from one set of primitive machinery to another. This argument is strengthened by the allusion in the contract, that in the event of the chain being stolen the loss should be made good by the payment of 27 Keratien.

The sprocket wheel which revolves the chain-of-pots was secured to the end of the horizontal shaft and the chain-of-pots could, therefore, be easily removed. It is accordingly quite possible that the land owners had several sets of machinery upon which an endless chain-of-pots fitted.

The paper was illustrated by a photograph of the papyrus, whence our illustration, Plate I, is taken.

The discussion on this paper was taken along with the following one.

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A Chain Pump Dredger of the Sixteenth Century.

By G. F. Zimmer, A.M. Inst. C.E.

(*Read at Prince Henry's Room, Fleet Street, February 6th, 1924.*)

A further addition to the above mentioned paper—"The Early History of Mechanical Handling Devices"—is an illustration which conclusively proves the use of the Chinese chain pump on the Continent as part of a dredger as early as 1560. It is similar to that illustrated and described by Johann van Zyl, and others, in 1734.

The Vasari Society unearthed the original drawing in the collection of His Grace the Duke of Devonshire, at Chatsworth, and published a facsimile of it in their *Proceedings*.[3] By the courtesy of one of our Members, a copy of this facsimile came into the possession of the Society, and was handed to me for the purpose of commenting thereon. The Vasari Society has kindly permitted the reproduction of their Plate (copies prepared by the Author were distributed to the audience). Plate II has been prepared from it.

Briefly, the history of this drawing is as follows: An important canal between the Ruppel and the Scheldt was completed in 1561, and in order to keep a record of this great achievement, the then Keeper of the Prints at the Royal Library at Brussels, commissioned the famous artist, Pieter Bruegel, to prepare a series of drawings relating thereto. In the opinion of the Vasari Society the original of the unsigned drawing you have before you is by Pieter Bruegel the Elder (1525-69) and is, so far as we know, the only one of the series he executed; the date assigned to this drawing is between 1562 and 1565.

The drawing, it must be remembered, is the work of an artist and not that of an engineer; it is a representation of a machine which actually existed before 1561 and which had, previous to that date, done actual work; it is not to be classed with pictures of mechanical devices, given by some early writers, which never existed save in their imaginations. We must, however, admit that the artist may have overlooked or misrepresented some of the minor details.

The dredger under consideration was used during the cutting of the canal before mentioned, and when depicted was lying near the bank of some river estuary in the Low Countries, probably on the Scheldt, for possible further use.

[3] Vol. VII., 1911-12.

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At first sight it is difficult to realise that the machine is actually a dredger, on account of the way in which the artist has shown the heavy timber baulks beneath the conveyor, they being apparently integral portions of the pontoon, which would make it impossible for the conveyor to be lowered to the ground of the waterway. If we take into consideration, however, that the machine had to be assembled on the pontoon and since all that kept it in an horizontal position during its erection and when out of use, was a couple of hemp ropes and a capstan, we must conclude that the baulks were removable, and that they were only in actual use during the erection and, later, when the task for which the machine was built was concluded, to prevent mischievous persons from letting the conveyor down.

According to the Vasari Society, the dredger was out of use when the drawing was executed and it had, therefore, been secured and protected by the precaution of inserting the baulks which were not easily removable, owing to their size and weight. If these baulks were integral parts of the pontoon the machine was not a dredger, and if not, what was it?

When using a dredger of this early type it was anchored in the waterway in such a manner that the paddle wheels were downstream, and as dredging proceeded the mooring rope was shortened in order to push the feeding end of the push-plate conveyor gently upstream. In this way the silt disturbed by the conveyor was assisted by the current on to the lower end working run of the conveyor. With this arrangement the barges for the removal of the spoil could be safely moored at the stern of the pontoon without coming foul of the paddle wheels.

The conveyor proper was on the same principle as the Chinese chain pump, but of a more advanced construction. The driving and delivery terminal was secured to the paddle wheel shaft and the feeding terminal could be raised or lowered by a capstan. The length from centre to centre would be about 35 feet, judging from the " Modder Moole " of Johann van Zyl, which was in use for a similar purpose at Amsterdam about 170 years later.

The upper run of the conveyor was the idle return and was supported by a wooden deck. The lower, or working run, was open at the feeding end for a few feet, beyond which it was provided with bottom and sides, upon and between which the silt was slowly scraped upwards by the endless conveyor chain, and delivered into barges placed below the main driving axle, or more likely *via* an inclined shoot, so that the barges, one of which is shown in the foreground of the drawing need not approach too closely to the paddle wheels.

The main timber stringers of the conveyor, at the feeding end were provided with wearing strips and bent upwards so that they could rest snugly at the bottom of the river at whatever inclination the conveyor might be at the time (this would have been a maximum inclination of 35 deg. to the horizontal). During the

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forward motion of the pontoon, as dredging proceeded, the lower end of the conveyor was pushed along the river bottom, and curved ends of the stringers prevented it from digging in too deeply but rather raised the end of the conveyor slightly when there was a tendency to enter too deeply into the silt.

Motive Power of the Conveyor.

Undoubtedly the two large paddle wheels were intended to be driven by the current of the water in which the dredger was anchored; they were mounted on a common square timber shaft, to which the driving wheel of the conveyor was likewise fixed. Since the dredger was used in the construction of a canal between two rivers, it had to work either in the streams or in the still waters of a canal. The amount of silt which could be removed depended entirely upon the power exercised upon the main shaft; the paddle wheels might have yielded sufficient power when the dredger was working in the river, but in still water it was nil. Apparently, therefore, the application of auxiliary man-power was added as an after-thought. This may be surmised from the fact that while the workmanship of the dredger generally was an excellent example of high-class millwright's work of the period, the supports for the men who were to assist in rotating the wheel—which was thus used also as a treadmill—were knocked together in a rough and ready way, and were certainly not in keeping with the rest of the work.

It is, therefore, probable that in fast-running water the dredger worked satisfactorily, that in sluggish water the power had to be amplified by the addition of a few men, while in still water it would be driven entirely by a large gang of men. Even with the combination of water and man-power, a satisfactory capacity may not have been obtained, owing to the considerable friction of the primitive conveyor. This seems probable because the dredger on the same principle illustrated by Johann van Zyl was provided with horse-gear for two animals in substitution of the motive power of the device under consideration. Moreover, stabling for two spare horses was provided from which it may be judged that the driving of such a dredger at full capacity was hard work, even for two horses.

I cannot conclude this short paper without expressing my appreciation of the privilege of belonging to this Society without which I should probably not have come into possession of so valuable a link in the history of conveyors—a subject which is very dear to me.

Discussion on this and the Preceding Paper.

The President said that the note on the chain of pots was one that should be preserved in the *Transactions*. As regards the dredger, it was difficult to believe that the paddle wheels shown would supply sufficient power in a sluggish stream—for only such needed dredging—to raise the silt; he could only suppose

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that the wheel was a treadmill merely. He moved a vote of thanks to the Author for his two papers, and this was heartily accorded.

MR. T. CLARKSON said he noticed what appeared to be two small cabins near the wheels. Could it be that these were to accommodate men to tread the wheel?

MR. H. G. GRAVES asked if any dimensions or scale could be inferred—say from the size of the door.

MR. RHYS JENKINS said it was just possible that the apparatus was known in or introduced into England, because a patent of importation was granted in 1568 to George Cobham, Tomazo Chanata, stranger, and their Company[4] for a machine which was said to dredge a channel 16 feet deep at low water. Conceivably this was a machine of the kind shown in the Vasari drawing. He remembered having seen something similar illustrated in Monconys's *Journal des Voyages*.[5] He considered both papers of extreme value.

MR. ZIMMER, in his reply, said he was quite satisfied that the apparatus was a dredger, and that it was capable of working as described, its capacity being dependent upon, and in proportion to, the power applied. The apparatus illustrated by Van Zyl of nearly a century later differed only slightly from it, and pointed to continuous use during a long period, so that the apparatus was a practical one.

CORRESPONDENCE.

MR. ZIMMER wrote that he had consulted the book[5] referred to by Mr. Jenkins, and found that the device there illustrated differed from the one used on the Ruppel-Scheldt Canal, in so far that two pontoons were secured at the required distance apart to support the conveyor between them. There was also one common shaft traversing the pontoons, with a similar pair of paddle wheels at the two extreme ends beyond the pontoons; the driving pulley of the conveyor was fixed to the shaft in a central position. The conveyor chain appears to have been the same as that of the device dating from 1560, but the wooden push-plates were shod with iron, and the terminal wheels were of iron instead of wood.

It was in use for dredging on the Rhine, at or near Esmery (Fort de Squin). A free translation of the French description is as follows:—

"We saw there a floating device for dredging the river channel; it consisted of an iron chain to which were attached buckets bound with iron at the edges, like spades. This chain passed between two boats to the bed of the river, and by means of two wheels was made to revolve from a point beneath the water to a level on which were fittted two (one, the other being under the water) iron rollers, along which the chain glides and ascends without difficulty. When it has reached the top, the buckets incline as they begin to descend, and empty the sand or refuse into a boat so placed as to receive it."

[4] Stat. Pap. Dom. Eliz., i., 56.

[5] Monsieur (Balthasar) de Monconys, *Journal des Voyages*, published at Lyons, 1665-6, Part 2 (1666), page 187.

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A Sixteenth Century Treadwheel for Raising Water,

By H. A. Sandford, M.A., F.G.S.

(Read at Prince Henry's Room, Fleet Street, February 6th, 1924.)

The ancient wheel which forms the subject of this note is situated at an old farm-house known as Great Kewland, in the Parish of Burham, about four miles N.W. of Maidstone. The name of the place has been variously spelled: it is not mentioned in the Domesday Survey, but it is recorded by Hasted, the untiring historian of Kent, about 1797, as Great Quling, being described as a manor. Another form of the name is Culand, as shown on the maps of H.M. Ordnance Survey.

Little is known or recorded as to the age and history of the wheel. Neither Hasted nor any earlier historian of Kent make any mention of it, but it is described in the Memoir of H.M. Geological Survey on the Water Supply of Kent as being in an Elizabethan house, this information being gathered from a publication called the "Rochester Naturalist." Another reference is that in Donald Maxwell's "Unknown Kent," in which a few particulars with a small sketch are given. The house bears the date of 1599 (1579?) over the lintel of a door, and this is an agreement with the architectural features which point to the house having been built about the middle of the sixteenth century. The wheel apparently was an integral part of the original structure, or was an addition of only slightly later date.

As will be seen from the accompanying drawing, the wheel is built up on a central axle made of one piece of oak, which forms also the winding drum for the well rope. The diameter of the drum is 11 inches, and its length about 2 feet: where it forms the axle of the wheel, its shape is roughly octagonal, having a width across flats of 14 inches. The total length of this axle from bearing to bearing is about 5 feet, and the support for the axle consists of a plain iron gudgeon inserted at each end and turning in a plain hole made in the vertical wooden support, the inner one of which is part of the framing of the house and the outer one of which supports the roof of the building over the wheel.

The main arms or spokes of the wheel consist of eight members, four on each side of the wheel. These main arms are of oak, having a section of roughly 4¼ inches square and a length of 12 feet 8 inches: where they cross each other, they

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are let in by the ordinary half-lap joint: rough packing pieces are inserted between the main spokes and the octagonal axle. The original wooden pegs for holding the spokes together at the joints remain, though additional fixings in the form of iron bands and fish-plates, variously secured by screws or nuts and bolts have been added, obviously at a later date. There are also eight (four on each side) subsidiary arms or spokes, having a section of about 3½ inches by 3 inches, let into and secured by wooden pegs to the main arms, and arranged so as to divide the rim or the circumference of the wheel into eight segments between the spokes.

Although the circumference of the wheel is thus subdivided, the actual construction of the rims involved the use of ten segments of varying lengths in each of the two rims, both of which have an average section of 4 inches square. Originally these segments were held together by wooden pegs, but the dovetail joints having at some time shown signs of parting, iron plates have been bolted or screwed on for security. The outside diameter of the rim is 12 feet 8 inches.

The tread of the wheel, which is 2 feet 10 inches wide, consists of flat oak boards about 1 inch thick, of such width that the tread, though polygonal, is practically circular. At the inside of the wheel, oak boards have been arranged circumferentially to a height of about 3 feet to prevent the operator from coming into contact with the adjacent wall. This lends colour to the idea that at one time possibly dogs were employed for working the wheel. It is in an excellent state of preservation and, despite its creaks and groans as it revolves, still performs useful service in raising water.

The depth of the well is given in "Unknown Kent" as 180 feet, and in the "Rochester Naturalist" as 120 feet. The author visited the site in December, 1923, and measured the depth, which he found to be 96 feet total, of which the water occupied 8 feet 2 inches. It is stated that, even in the driest season, the water never sinks lower than 2 feet 6 inches from the bottom. It is evident that the well is sunk to the bottom of the chalk, where the water is held up by the gault clay, which the writer's brother, Dr. K. S. Sandford, computes to be at a depth of 106 feet below surface at this point.

The author calculates that a man raising water from this well develops 0.11 horse-power, no allowance being made for the weight of the rope or for the friction of the wheel. This figure compares well with that obtained from a similar wheel at Carisbrooke Castle, where a donkey is used, which is estimated to exert 0.2 horse-power.

The writer is indebted to the owner of the house, Mr. Twort, for his kindness in allowing these details to be investigated.

The paper was illustrated by a large scale drawing and a photograph of the wheel, from the former of which Plate III has been prepared.

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After a vote of thanks to the Author for his paper had been carried by acclamation, the

DISCUSSION

was opened by

Mr. H. W. DICKINSON, who remarked that as the well-known wheel at Carisbrooke Castle, Isle of Wight, had been referred to, he might mention that some years before the War he had taken all particulars, and a model of it was now in the Science Museum, South Kensington. (Here the speaker exhibited a drawing of this wheel.) The date of this wheel was stated to be 1588, and although he was unaware of any documentary evidence confirming this, he was ready to believe it. As there was much similarity between this wheel and the one described in the paper, he was prepared to accept the date given by the Author. He would be glad to know whether there was any evidence of the introduction of wheels of this construction from abroad in the sixteenth century, or whether they could be considered a development made by native millwrights.

Mr. A. TITLEY said this wheel certainly was an early example of the millwright's art, but he would not like to give it a date. Too much stress must not be laid on the construction, which was a type that lasted some hundreds of years. The arms surrounding the square were known as clasp arms. The use of iron for the gudgeons showed that the wheel could not be older than the sixteenth century. He was not sure that the Author had got this detail correctly represented on his drawing.

Mr. RHYS JENKINS said there were a number of these wheels still in existence; there was one in Hertfordshire which was of similar construction, but he believed it was not earlier than the 17th century. He would draw attention to the machine patented by John Payne in 1573. This was a combined hand and tread mill,[1] the construction of which showed clasp arms.

Mr. LOUGH. PENDRED confessed to some surprise that the horse-power was as much as 0.11; he drew attention to the method of keying the wheel on the shaft, which he thought might be the forerunner of "staking-on."

Mr. R. H. WILLIS said that in the Isle of Thanet about 10 miles from Broadstairs, at an old farm house, there was a donkey wheel which was frequented by visitors as being quite a show object. He could not give details of the construction.

Mr. H. G. GRAVES said that in Cochin China and S. India dash wheels 15 to 20 feet diameter, made of bamboo, worked by a number of men treading on the outside, were used for raising water 1 or 2 feet for irrigating the paddy fields.

Mr. J. A. HALL said there was a picture at the Lateran, "The Legacy of Rome," showing such a wheel for raising water.

Mr. E. W. HULME mentioned that Payne's mill was intended for the Bridewell as a means of punishment.

[1] Described and illustrated in "The Engineer," 1918, ii. 534.

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Mr. SANDFORD, in replying to the discussion, said the spokes of the wheel were, as far as he could see, of the same age as the rest of it. He had no evidence as to the date of the wheel. As the farm-house was dated 1579 or 1599—the crudeness of the carving rendered the third figure difficult to decipher—and as water could not be got from anywhere except from the well, he could see no reason for supposing that the wheel was not constructed when the house was built. He had heard of the donkey wheel in the Isle of Thanet, and had intended to have visited it.

CORRESPONDENCE.

Mr. GRAVES wrote that since the meeting he had visited the donkey wheels in Hertfordshire mentioned by Mr. Jenkins. They are two in number, close to Kensworth Church, some two miles south of Dunstable. Formerly there were several on the line of the chalk downs between Studham and Church End, Cuddington, but now only one is in working order, and that is used daily. As much as 4,000-5,000 gallons of water have been raised by it in a week from a depth of some 200 feet. The well is now said to be 229 feet deep, and at the time of my visit (March, 1924) to contain 56 feet of water. It had been deepened some four years ago. The wheel itself is 4 feet wide and about 14 feet in diameter. The axle is of oak, 4 feet in circumference and 14 feet long, with iron gudgeons at the ends running in bearings in the walls. The bucket holds 28 gallons, but formerly held 32 gallons. The old donkey, fat and comfortable in spite of its 20 years, took 3 to 5 minutes to make a wind. Sometimes the man got into the wheel and walked alongside the donkey. In its early years it used to work with its mother, and there was just comfortable room for them both between the spokes. The bucket runs down by its own weight, though it sometimes requires a little assistance, as the wheel is slightly out of true: the speed can be controlled by a strap brake raised by a hand lever to bear on the underside of the wheel. The photograph (see Plate IV), for which I am indebted to Mr. W. N. Henman, of 38, Western Road, Bedford, shows the construction clearly. A similar illustration, but showing a little more of the axle with the rope winding on to it, is to be found in the Victoria County History for Hertfordshire.

At the next farm, where an oil engine and pump are now used, the wheel has the date 1688 cut on it, and is practically of the same construction, except that there are only four instead of eight spokes intermediate of the four main spokes on each side. It is, however, slightly larger, say 15 feet instead of 14 feet in diameter, and the axle at the spokes is $4\frac{3}{4}$ feet in circumference. At the working well the rope goes from the axle direct down the well, but at the other it was led over a pulley suspended from the roof.

Mr. A. M. BUSHELL wrote that some years ago he had seen a treadwheel at Bovey Barton, near Beer, Devon (see Plate V), but he was not in possession of any particulars except that the well was supposed to be 180 feet deep.

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Evelyn's "Circle of Mechanical Trades,"

annotated by

A: Forbes Sieveking, F.S.A., F.R.Hist. S.

(Read at Prince Henry's Room, Fleet Street, February 6th, 1924.)

One of the objects the Royal Society set before itself on its foundation in 1661, as shewn by the dedication to Lord Chancellor Clarendon by John Evelyn of his translation of Gabriel Naudé's *Advis pour dresser une Bibliothèque*, 1627, which appears under its English form of *Instructions concerning Erecting of a Library*, 1661, in addition to the study of the higher physical and mathematical sciences, was to collect and chronicle a history of the minor arts and trades. There were few subjects that Evelyn did not take up to some purpose, and this was one of them, so we find that he prepared the holograph document[1] printed below. Obviously it is merely a classified list of trades, and can only have been meant as a table of contents to the projected work.

Quite probably Evelyn took his title: *The History of Arts illiberall and mechanick* from Hartmannus Schopperus's *De omnibus illiberalibus sive mechanicis artibus*, an octavo volume published at Frankfort in 1574,[2] illustrated by Jost Amman (1539-1591), a Swiss settler in Nuremberg.

Evelyn's MS. is dated at the end of 1660, Jan. 16, and confirmation of the date is afforded by an entry in his *Diary* under this date: "I went to the Philosophic Club, where was examined the Torricelian experiment. I presented my circle of Mechanical Trades. . . ."

What happened appears to have been as follows.[3]

Jan. 9, 1660/1.—"Mr. Evelyn to show his Catalogue of Trades." (p. 10.)

Jan. 16, 1660/1.—"The Catalogue of Trades brought in by Mr. Evelyn and that of Dr. Petty were referred to them and Dr. Merret to be compared, methodised and returned to the Society." (p. 12.)

March 25, 1661.—"Dr. Merret was to be asked for the Catalogue of Trades which he took of Mr. Evelyn's and Dr. Petty's." (p. 19.)

May 22, 1661.—"The business of the History of Trades was appointed to be discoursed of at the next meeting." (p. 24.)

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[1] Preserved in the Royal Society Library, Guard Book, Vol. 3, "Mechanics and Trades," I.M.S., No. 1.

[2] A still earlier edition appeared at Frankfort in 1568, entitled: *πανοπλια, omnium illiberalium mechanicarum aut sedentiarium artium.*

[3] T. Birch, History of the Royal Society (1756), Vol. I. p. 10, et seq.

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(There is, however, no reference to the matter in the minutes of the meeting on May 28th.)

Feb. 26, 1661/2.—" Sir William Petty promised to produce on that day fortnight his paper concerning Trades."

(There is, however, no reference to the matter in the minutes of the meeting on March 12th.)

The only further reference to the matter occurs in a letter in French, dated September 21st, 1661, from Henry Oldenburg, the first Secretary of the Royal Society, who edited and contributed to the first five or six volumes of the *Philosophical Transactions*, to Benedict (or Baruch), Spinoza, the philosopher: (Translation) :—

" We are here quite busy in our Philosophical College in making experiments and observations, according to the measure of our strength; and we are trying to trace a history of the mechanical arts, convinced as we are that the forms and qualities of things can be perfectly explained by mechanical principles, and that all the effects of nature reduce themselves to movement, form, to the action of parts and the different complications resulting therefrom without there being the smallest necessity to have recourse to those inexplicable forces and occult qualities which are the asylum of ignorance."

Here, so far as we know, the matter was dropped. No doubt the Royal Society found that it was attempting too much.

Among the trades and articles enumerated by Evelyn are some that are now obsolete or are known nowadays under a different name, such as the following:—

1. Brasil grinder: Brasil is a red dye wood.
   Cordwayner: Bootmaker.
   Crusemaker: Oil lamp maker.
   Flesher: Butcher (used still in Scotland).
   Garbeller: One who cleaned spices from refuse.
   Girdler: Maker of girdles or waistbelts.
   Horner: Worker in horn.
   Inkle: Broad linen tape.
   Lacemaker, galloone: Galloon is braid with gold or silver threads.
   Milaner: Trader in Milan wares, e.g. silks, ribbons.
   Paynter-stayner: Painter of Coats-of-Arms.
   Pinner: Pin-maker.
   Poynt-tagger: One who puts tags on laces.
   Razer of sattin: Raiser, one who cuts pile close.
   Say and searge maker: Say is a cloth like serge.
   Seeder-man · Seedsman, originally a sower of seeds.
   Shingler: Maker of wooden roofing (used still in U.S.A.).

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Throwster: One who twists silk into thread, originally a woman, hence the termination "ster."

Tike maker: Bed tick maker.

Tucker: Fuller of cloth.

Whitster: Bleacher, "ster" indicates this was a woman's occupation.

2. Fripperer: Old clothes dealer.
3. Embailer: Packer.
4. Collyer: Charcoal burner.

Keeper, art of cicuration means taming, domestication.

Austringer: Keeper of goshawks.

6. Diving, urinator: Urinator is a diver.
7. Grotesco-worke: Decorative painting, consisting of animal forms fantastically combined with foliage.
8. Pietra-comessa: Stone inlaid.

Smigmaticks: Cleansers, detergents.

Lapis luminans Bologniae: Bononian phosphorus, barium sulphate fused with carbon, which is slightly phosphorescent.

Chamelotts: Cloth of camelhair.

Grogram: Cloth of silk and mohair.

Plastrons: Fencer's leather-covered breast pad.

Prince Rupert's new way of engraving: Mezzotint.

Discussion.

Mr. E. W. Hulme said it was interesting to learn what a leaning towards applied science the Royal Society had at its outset; it had since restricted itself greatly, leaving the field open for other Societies. The Author's opinion that the *Circle of Mechanical Trades* was based on Schopperus would be strengthened if it could be shown that it had been copied, and was not a list of trades known in England. Schopperus was interesting because of the pictures of trades by Jost Amman. This class of book became popular in Germany, and eventually developed into the encyclopaedia, such as Diderot's *Encyclopédie Méthodique*. He would like to see the *Circle* printed.

Mr. H. A. Sandford said that in early days the Royal Society certainly covered a wider field than at present, e.g., there were some amusing and curious experiments by Boyle and Wilkins on the behaviour of animals recorded.

Mr. Sieveking, in reply, said he was sure the Royal Society would have no objection to the *Circle* being printed.[4]

[4] This permission has been obtained, and we take this opportunity of recording our obligation to the Council therefor, also for the photograph from which Plate VI. has been prepared.—Ed.

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John Evelyn's "Circle of Mechanical Trades."

The History of Arts Illiberall and Mechanick Alphabetically or according to their Antiquity, Succession, Dependance, Dignity, Necessitie, etc. in Bookes of

1. Usefull & purely Mechaniq.
2. Meane & Lesse honourable.
3. Servile.
4. Rusticall.
5. Female.
6. Polite and more Liberall.
7. Curious.
8. Exotick and very rare Seacrets.

1. USEFULL AND PURELY MECHANIC.

A

Apothecary
Amber-workers
Armorer
Anchor-maker

B

Baker
—Bread
—Suggar
Barber
Basket-maker
Bell-founder
Bellows-maker
Bit-maker
Boate-maker
Book-binder
Brasier
Brasil-grinder
Brewer
Brick-maker
—Playne
—(pan) Tyle
Bell founder
Bricklayer
Brush-maker
Bugle-maker
Buckle-maker
Buckram-maker

C

Cabinet-maker
—Boxes
Cage-maker
—Plate-worker
Calendrer
Card-maker
—Paste board
Coulsor
Cord-wayner
Carpenter
Cartwright
Carver
—in wood
—in stone
Chandler
—wax
—tallow
—ship
Compass-maker
Cheese-monger
Clasp-maker
Clothier
Cloth-worker
Cloth-drawer
Coach-maker
Coller-maker
Colour-maker
Coyner
Comb-maker
Cooke
—Carver
Confectioner
Cooper
—Wine
—Dry Vessells
Cruse-maker
Copper-smith
Crosse-bow-maker
Cruett-man
Chirurgeon
Currier
Cuttler

D

Drawer for ye Embroderer
Dier
—silke
—Linnen Cloth
—Stuff
Diaper
—Wollen
—Stuff
—Linnen
Dice-maker
Drougist
Drum-maker

E

Edge-toole-maker
Embroderer
Embosser

F

Farrier
Feather-maker
Fell-monger
Fish-monger
Fish-hook-maker
Flax-dresser
Flesher
Forger
Founder
Frienge-maker
Fuller
Fourbisher
Furnace-maker
Furrier
Fustian-dresser

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G

Garbeller
Grinder
Glasse-worker
Glasier
Girdler
Glover
Gold-beater
Gold-smith
Gilder
Glew & Size-maker
Gun Smith

H

Haber-dasher
Harness-maker
Hat-maker
Hatband-maker
Hemp-dresser
Hoope-maker
Horner
Hosier

I

Inke-maker
—Penne
—Printers
—Inke
Inkle & Tape-maker
Inlayer
Instrument-maker
Ioyner
Iron-monger
Iron-founder & finer

K

Knitter

L

Lace-maker
—bone
—silver
—gold
—silke
—galloone
Lanterne-maker
Lath-maker
Leather-dresser & seller
Letter-founder
Lime-burner
Looking-glasse grinder
Lute-string crib-maker
—Cattlines
—Deares } Sinues
—Sheeps } & gutts
Lute-maker
Lead-smelter

M

Masson
—Free
—Marbler
Mast-maker
Matt-maker
—straw
—rush
Mercer
—Jack of all Trades
—Silke
Mill-stone-maker
Miller
Mill-wright
Millaner
Minerall-Man
Mint-master: Man

N

Nailer
Needle-maker
Net-maker

O

Ordnance-caster
Organ-maker
Oyle-Man

P

Paynter-stayner
Paper Maker
—Mills
Parchment-dresser
Pastry-man
Paver
Pencill-maker
Perfumer
Perruck-maker
Pewterer
Pinner
Pipe-maker
Pipe-bearer
Pitch-maker
Plasterer
—Pargetter
—Frett-worke
Plumber
Poynt-tagger
Poulterer
Potter
Presser, hott-presse
Pumpe-maker

R

Rasper
—Wood
—of Harts-horne, &c.
Rayers of Sattin
Razor-maker
Rope-maker
—Cables
—Cords
—Match
—Pack-threid
—Shop-threid
Red-lead-maker

S

Sadler
Salter
Sawyer
—Saw Mill
Say & Searge-maker
Seeder-man
Sheath-maker
—Scabbards, &c.
—Cards, &c.
Shear-man
Shingler
Shipwright
—mast-maker
—pully-maker
—oars-maker
Saile-maker
Shoo-maker
Sieve-maker
—Lattice
—Window
—Tiffany
—Wire
Silke-man
—Ordering the wormes
Silke-weaver
—Stockings, &c.
Silke-dier
Silver-Smith
Skinner
Skrew-maker
—Small worker

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Smith
—Black
—Jack
—Lock
—Anker, &c.
Sope-boyler
—Castle-Soape
—Wash balls
Soymaster
Spurrier
Starch-maker
Stationer
Suggar baker
—Ingenio
Sword-maker

T

Tanner
Tapistry-maker
—Arras
Tayler
—Stitcher
—Bodys maker
—Belly piece maker
Thimble-maker
Thatcher
Threid-maker
Throwster
Tiffany weaver
Tike-maker
Tin-man
Tirer
Tobacco-man
—Curer
—Cutter
—Pipemaker
Teethdrawer
—Setter in of Artificial
Trumpet-maker
Trunke-maker
—Jacks
—Bottles
—Bucketts
—Hanapers
—Gambujos
—Port-manteau
—Hatt Cases, &c.
Trunkes to Shoote in
Tucker
Turner
Tin-smelter

V

Victualler
Vintner
Virginall maker
—Harmonicall
—Pedalls, &c.
Upholster

W

Weaver
—Cloth, wollen
—Linnen, Silke
—Velvett, Flowerd Worke, Diaper, &c.
Weight-maker
Wheele-wright
Whitster
Wire-drawer
—Gold
—Silver
—Copper
—Iron, etc.
Wood-mongre
Wool-carder
—Spinner
—packer
Worme-maker
—for refining alcohol)

2. MEANE TRADES.

Baubles for Children
Broome-maker
Chimney Sweeper
Cobler
Corne-Cutter
Fripperer
Heele-maker
—Lasts
—Patens
—Cloggs, &c.
Pedler
Rat-Catcher
Sow-Gelder
—Colts
Tinker

3. SERVILE.

Carrier
Carter
Porter
Postillion
Sedan man
Litter man
} Vehicula

Embailer
Packer
Stower
Tankard-bearer
Grinder
—Knives
—Razors, &c.
Hostler
Porter

4. RUSTICALL.

Husband-man
Vigneron
Gardiner
—Apiary
Grasier
Shepheard
Maulster
Bark-stripper
Collyer
Mole-Catcher
Huntsman
—Wood-man
Keeper
—Parker
—Warrener
—Subterranean art of Cicuration
Fowler
—Aviarier
—Decoys
Fisher
—Vivaries
—Piscinar
Faukner
Austringer

5. FEMAL ARTIFICES.

Preserving
—Wet
—Dry
—Candiery, &c
Flowers & Nuns worke
—Dried—Naturall
—Gum
—Silke-braide
—Skane Silke
—Cotton
—Horne
—Straw

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—Silke Cord
—Wafer
—Callico
—Paper
—Glew & Waxe
Hollow-worke in Silke
Moulding in wax
Cutt & needle works in point of
—Venize
—Genes
—Paris
—Sedan
—Aurillac
—Ragouse
—Gimpe
—Eschallop
Spinning
Semster
—all the several sorts of stitches
Lawn-dresse
Bleaching
Mid-wifery
Cosmeticke

6. **POLITE & MORE LIBERALL.**

Merchand
—Exchange
—Keeping the Booke
—Cash. &c.
Navigation
—Shipwright
—Pilot
—Mariner
—Waterman
Art Military
—Drilling
—Fortification
—Pioner
—Gunner
Diving, Urinator
Enginere
State (Stage) plays
—by mutes
—by puppetts
Horse breaker
Coult breaker
Dauncing
—Ropes
Herauld
Vaulting
Wrestling
Fencing
Swiming
} Gymnastica
Legier de maine
Fontanier
Gauging of Vessells

7. **CURIOUS.**

Enamelling
Paynting
—Oyle
—Miniature
—Mosaic
—Fresco
Anealing in Glasse
Glassworke & making
Printing
—Rolling press
—Cloth
—Leather, &c.
Gilding of
—Frames
—Leather
—Mettalls
—Bronzing
Engraving
—Etching, &c.
Sculpture
—in Brasse
—Casting
—Plastica, &c.
Spectacle-maker
—and all opticall glasses
Grotesco-worke
Mathematical Instrument-maker
Dyalls, Comp. Hours
Clockes
Watches
Dialls
} and all Automata
Lapidary
Gun-powder maker
Alchimy
—Bay Salt
—White-Salt
—Alum
—Coprose
—Salpeater
—Sulphur, &c.
Fire-workes

8. **EXOTICK & VERY RARE SEACRETTS.**

Mosaic worke
Pietra-comessa
The Red floores of Venice and other Tarraces
Marble-paper
The Vernish of Lak wrought in wth Enamell
All the sorts of Vernishes
The white Vernish for Paper, Stayn'd Calicos, Indian workes & pintados
Turke
Persian
} worke
Porcellan
Vessells of Twiggs, &c.
Balls of Bolognia & all Smigmaticks
Inventions to take spots out of Cloth & Silke
Lapis Luminans Bologniae
The Inflamable Stone
Chamelotts
Grograms
} their mixture
Stuffs of Rinde of Trees & Grasses
Frost-hangings & flux worke
Armour & Coats of Maile
Lutestrings, Cent. Taffitas
Bent, Cotton, Leather, &c.
Plastroons
Tarpolin & Gum-ings to resist wett
Table-booke Vernishes
Asse-skins for musicall Compositions, &c.
Chiagrine, Seale-Skins & Boyled Leather
Marrocine & Turkey Leather, Buffs
Indian Wax-worke & making of hard wax
China Vernishes, and Plate Inlayinge emboss'd
Thrieds & stuff that consume not in ye fire
Di(e)ng of Stones, Ivory mettall, wood, parchment, &c.

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Tincture of Mettalls, Blanches, &c.
Mirroires & mixtures of Steele, &c.
Damascking of Swords, Armour, &c.
Pasts, Artificiall Stone Pearles, Marbles
Monkes-gilding
Moulding in Plaster & coated wth Lead
Moulding wth Linnen
Paper & past for Statues & Visors after the manner of Vincentio Barrochi
Marbling of Stucky-Statues
Embalming after Billins & other wayes
Artificiall Pomanders
Making of Spunke & Touch-wood
Moulding & Imprinting in wood, Horne Tortoisshell, &c.
The Plumary-Arte
Chinest-Inke
Malleable or more flexible Glasse
Strewing & Coating of Timber to preserve it from rotting
Coating of ones flesh with an artificial past to preserve them even in the fire, or molten lead
Cements, Soders and Lutations
Artificial Colours of the rarest sorts as Ultramarine Lake, &c. Ceruse.
Seacret-wayes of writing
Hardning of tooles to cut porphyrie, &c.
Burning-glasses
Aeolipiles
Thermometers
Wind-Guns
Ventiducts
Caliducts
Hardning of tooles to cutt Skeetes
Pr: Rupert's new way of Engraving
Lamps to last long
Inventions to fly, &c.
et sic de Caeteris.

A Booke of the Tooles, Modells and all the Utensils pertaining to the Severall Trades, &c. designed in Perspective and exactly proportion'd.

J. Evelyn:
1660
Jan: 16:

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The Rastricks—Civil Engineers,

By H. W. Dickinson and Arthur Lee.

(Read at Prince Henry's Room, Fleet Street, March 5th, 1924.)

In this paper is presented some account of a family of engineers who exhibited hereditary ability similar in kind to that of the Stephensons and the Brunels, though lesser in degree.

The family originated in what is now the parish and township of Rastrick—mentioned as Rastric[1] in the Domesday Survey, 1083—in the W. Riding of Yorkshire, on the River Calder, 3½ miles N. of Huddersfield and 5 miles S.E. of Halifax. In the Manorial Rolls of the township the name of Henry, the son of John de Rastrik is recorded in 1272[2], and many other persons of the same name are mentioned during succeeding centuries. Perhaps the most important of them was Thomas de Rastryk,[3] who in 1397 was Constable of the township. It is a reasonable assumption that some of these were forbears of a certain John Rastrick (1651-1729), who in the troublous times of the Revolution of 1688 became impoverished and migrated to Morpeth in Northumberland. His son William (1695-1772) was a millwright at Morpeth, and his grandson John (1738-1826) followed the same occupation. It is with the latter that our story opens.

In a trade circular of his,[4] undated but watermarked 1794, he describes himself as " Engineer, mill-wright, pump and patent churn maker." Amongst work that he executed he cites " improved Machines for thrashing Corn " and " Steam Engines on a new Construction." The churn was patented 8th August, 1777 [No. 1166], and styled by him the " Imperial barrell churn." It was fitted internally with ribs, and had a handle for rotation. It was the earliest churn of any kind to be patented. What his steam engine was, unless it was an atmospheric engine, we do not know.

With regard to the nature of the improved thrashing machine we are not on much surer ground. The beater thrashing machine is usually ascribed to Andrew Meikle, and the genesis of its invention is stated to be as follows.[5]

A model was sent to him by Sir Francis Kinloch, of Gilmerton, Bart, who had based it on a machine he had seen erected by a Mr. Smart in 1772 at Wark, near

[1] Turner, *Brighouse, Rastrick and Hipperholme*, 1893, p. 33.
[2] *Loc. cit.*, p. 46.
[3] *Loc. cit.*, p. 40.
[4] In the possession of one of the Authors. See Plate VII.
[5] General view of the Agriculture of the West Riding of Yorkshire, by Robert Brown, farmer, at Markle, near Haddington, 1799, p. 58.

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Morpeth. This model was defective in that the operation was accomplished by rubbing instead of beating. Meikle thereupon experimented with it, and in 1785 succeeded in producing another model with beaters, and in the following year a machine was made that worked quite well. A patent was then applied for, and was obtained in 1788. Rastrick may quite probably have been the constructor of the Wark machine, as that place is so close to Morpeth, but the point is did he introduce the successful beater type, and if so, when? In an engraving[6] of his machine, undated but watermarked 1815, he states that it was "erected 1778." The resemblance between this engraving and Meikle's patent drawing, 1788, is too close to be accidental.

The earliest record that the Authors have found of the erection by Rastrick of a thrashing machine is in 1790[7]. Particulars of subsequent machines erected at Brightwellgrove, Oxon, and at Wimbledon, Surrey, are extant.

We have a trenchant opinion of Rastrick's machine in a letter from John Rennie to James Watt in 1791:[8] "I have by this evening's coach sent you a copy of Mr. Meikle's Plan and Specification of his Thrashing Mill as taken from the Patent Office. Will you be kind enough to look them over and write me your opinion, as upon that I shall take my determination in respect of trying the right. Rastrick's machine is a notorious theft."

We may be sure that Watt would dissuade Rennie from contesting the patent, as he had great respect for patents in general and his own in particular. We infer also from this letter that Rennie did not think that Meikle's invention was novel.

The author we have quoted[9] says, "Mr. Meikle was the first man that constructed a machine capable of separating the grain from the straw in a proper manner. We speak with confidence on this subject, because we have had the best opportunities of knowing it in every stage, and are warranted in attributing the merit of the invention solely to Mr. Meikle." Such might be the author's opinion, but he admits that "Mr. Meikle has hitherto,[10] from causes unnecessary to mention, received little benefit from his patent right."

It is evident from the foregoing statement that the patent was assailed, and that this was the case is confirmed by a memorandum by Rastrick on the back of the engraving alluded to above. In this memorandum the date 1798 occurs, and the pertinent part is as follows:—

"The T.-M. is of greater utility to the Agriculture of this Kingdom the[n] all machines hitherto Invented, and the loss I suffered by the law Sute in Setting

[6] In the possession of one of the Authors.

[7] General view of the Agriculture of the North Riding of Yorkshire, p. 81. "The thrashing mill was introduced into this Riding by E. Cleaver, Esq., of Nunnington, about 1790, for whom Rastrick, of Morpeth, erected one, at an expense of about £100."

[8] Boulton and Watt Collection, Birmingham.

[9] Brown, General view of the Agriculture of the West Riding, 63.

[10] *Loc. cit.*, 62.

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the Patent aside is to me a very considerable sum—and no reward for my Invention. Andrew Meikle that took out the Patent for the machine had been working for me—I had made them nine years before he ever saw them, but he and a Scotch part sopter (?participator), who got the Patent taken out first, was secure. They offerd me any Shair I demanded of that gaind by the Patent if I would joind them. The[y] keep the Action in the Court of Kings Bench Six terms but never did come to Tryal for all the expence I was at I only got a Tax Cost of £123 10 6."

Search among the Chancery suits at the Record Office has failed to reveal any trace of this action; it may have, of course, been settled out of Court, but, if so, the reference to taxed costs needs explanation.

A controversy as to the invention of the thrashing machine raged fiercely about 1810, when a subscription was being promoted for the benefit of Meikle, then in reduced circumstances, but the authors have not been able to glean from it any pertinent facts, and they therefore leave the matter for future elucidation.

A portrait of Rastrick exists (see Plate VIII); on the back is a note: "He conceived and executed a plan from which the stupendous cast iron bridge over the River Wear at Sunderland was made." This remarkable structure was built in 1796 under the patent of Rowland Burdon, September 18, 1795 [No. 2066], who is credited with being both "engineer and paymaster," so what share Rastrick had in the work it is difficult to say; it can only have been a minor one. It is also stated that "he was the inventor of the cylinder as used in flour mills."

John Rastrick appears to have established himself in London in 1798 at 15, Charing Cross, and later at 18, George Street, Adelphi, both addresses affected by engineers at that period. Probably he was extending his connection. In 1808 he retired to Morpeth, where he died on June 8th, 1826, at the advanced age of 88, and was buried in St. Mary's Parish Churchyard.

John Rastrick married in 1774 Mary Urpeth, of Rothbury, and had three sons and three daughters; his fourth child and eldest son, John Urpeth, was born on January 26th, 1780, at Bullers-green, Morpeth. He received the education of the village school, and if he made any mark at all it was by his liking for mathematics. At the age of fifteen young Rastrick was apprenticed to his father, and when he was out of his time he made the wise decision to leave home in order to gain experience; he went south, and for a few years worked at Ketley Ironworks, in Shropshire, at that time under the enlightened management of William Reynolds, one of the most up-to-date establishments in the country. Here Rastrick made himself familiar with the properties and moulding of cast iron, the use of which was being rapidly extended for general engineering work, and he began to be remarked for energy, perseverance, and sound mechanical judgment, qualities that distinguished him through life. We find a John Rastrick acting as resident

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engineer under Trevithick on the Thames Driftway in April, 1808,[11] and he was there in November of the same year, when the work was shut down. If he were our Rastrick, as we believe he was, this connection with Trevithick would serve to explain the next move, which was to join John Hazeldine, of Bridgnorth, in the latter's foundry business.

This had been in existence since 1803,[12] if not earlier. In 1806, Hazeldine was (next to Whitehead, of Manchester) the largest maker of Trevithick engines, to judge by a statement[13] of royalties paid to Richard Trevithick & Co. It was in these works that the London Locomotive of 1808 was built; in Rastrick's evidence on the Liverpool and Manchester Railroad Bill in 1825 he said: "About ten or twelve years ago I made one for Mr. Trevithick, the person who had the original patent for making it; this was exhibited in London; I did not see that myself. A circular railroad was laid down, and it was stated that this engine was to run against a horse, and that whichever went a sufficient number of miles was to win."

For the next year or two we have no evidence of what Rastrick was doing; all the papers of the firm Hazeldine, Rastrick & Co. have long been destroyed. Fortunately we have some portion of Trevithick's correspondence with the firm from 1812 to 1815, owing to the fact that the former's rough draft letter-book covering this period has been preserved. We have also a few letters in 1812 from Rastrick to Simon Goodrich,[15] the assistant of General Bentham, at the Navy Office in London. In one of these letters Rastrick says:—

Bridgnorth, Novr. 15, 1812.

Dr Sir,

You will think me verry remiss in not writing you sooner; after I recieved your Letter of the 2nd Septr. inclosing one to Mr. Mitchell I set out from home, on the 9th of the same Month and after having gone thro' Hereford, Worcester, Glocester and Wiltshire, I went to Bristol from thence I crossed the Bristol Chanel and went thro the Ironworks in South Wales. I then went down to Swansey and thence to Mr. Davenports; our men had got the Engine put up as also the first Shaft, Fly Wheel & 16 ft Spur Wheel; Counter Shaft, Flywheel & 8 ft Spur wheel, and preparations were made to put the cast Iron Pipes down the Engine Pit but Mr Davenport was determined to go no further so I ordered our Men Home. I understand Mr. Morrice is in Treaty with some Gentlemen to take Mr Davenport's Share of the Concern.

I certainly must say that the Engine, and Engine House, Pump Beames,

[11] Life of Trevithick, i. 270, 276.

[12] Life, *Loc. cit.*, i. 240, ii. 3, under date Sept. 23, 1803, Trevithick writes to Giddy: "There are six engines nearly finished at Coalbrookdale and seven in a foundry at Bridgnorth."

[13] Preserved at the Science Museum, South Kensington.

[14] Life, ii., 36.

[15] For an account of him, *see Trans.* III. 1.

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Flywheels, shafts, Spur wheels, Carriages, Training, &c. &c. is as well executed as any work in the Kingdom, and I am sorry it has not been so far finished that we could have set it to work.

I returned to Swansey and got myself & Horse on Board the Packet and crossed over the Bristol Chanel to Ilfa Coomb in Devonshire from thence I rode down to Cornwall by way of Barnstaple, Launceston, Bodmin and Truro—I got an introduction to several of the principal Miners and then went to Redruth & Cambourn. At the latter place I met with Woolfe and find he has got the superintendance of the Engines at Oatfield, Cranver and Wheal Abraham Mines, a little distance from Cambourn. I understand that he had Orders to put up a double 60 inch Cylinder 8 feet Stroke on his Construction at Wheal Abraham (I have since heard that it is countermanded) Trevithick lives within 2 miles of Cambourn and not being at home I went down further to a Mine near Marrizion where I was invited to look at an Engine put up by Woolfe of about ten Horse Power; it was verry well fitted up but extremely complicated and I was told was worked by one third the Coal of B & W Engines—unfortunately it was not at Work when I saw it. I therefore had not an Oppertunity of judging of its Performance; the Piston is on Cartwright's Plan. I have since heard that the Engine has got into discredit and was the Reason of the Order for the Engine I mentioned before being countermanded. I never had any good Oppinion of Woolfe's Engines, for the Complication was in my mind sufficient to condemn them. I next went to Pensance and there went to see that remarkable Curiosity The Logan Rock which you have no Doubt heard or read of. It is an immense large Stone of ((according to me Calculation), about 80 Tons and stands upon other Rocks (which project out into the Sea, elevated about 100 feet) and so nicely ballanced that you may give it a considerable vibratory motion without being able to overturn it by almost any Power you could bring to act on it in the Situation in which it is placed. It is truly a natural Curosity; after this I rode to Lands End and returned to Pensance.

On my return the next Day I found Trevithick at home, I spent several days with him and he went with me to see several People who gave me orders—I mentioned to him that I was going to see the Breakwater at Plymouth, he thereupon agreed to accompany me: I went to see an Engine put up by Trevithick, which works with less coal than any Engine I know of. It is a single Power Engine, with an Air Pump and Condensor, only two nozzle valves, but the principal Advantage it has is by working with a Steam of high elastic Power and shutting off the Steam at one-third the Stroke, it expands for the other two-thirds of the Stroke, is then so far lowered in Power as not to exceed the Power of the Atmosphere and of course becomes verry easily condensed.

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If an Engine is properly calculated, well-executed, and put together, on this Plan I am persuaded it will consume less Coal than any Engine whatever as it can be made so extremely simple.

Trevithick and I set out and rode along the Southern Coast of Cornwall to Plymouth. I delivered your letter to Mr. Mitchell who conducted us thro the Dock Yard, but I was by no means so well pleased with it as I was with Portsmouth. We now went to Oreston Quay to see the Manner in which the Business was conducted there of getting and Shipping the Stone—we found the Principal Quay was rendered quite useless as it had sunk according to the information we had recieved about 20 feet not perpendicular but by inclining in such a Way that should they continue to build on it, the Foundation will probably be uppermost as it seems to turn thus [sketch omitted]. They were building on it when we were there altho it is evident that no vessel can come alongside of it, since the Mud or Soil is hove up in such a way as not to allow a sufficient depth of Water. The Method in which they get the Stones and convey them to the Quays; the Construction of the Vessells the way of Loading and discharging is in my oppinion, the *verry verry worst* that could be thought of by the greatest Bungler that ever was. You are I suppose acquainted withe the Construction of the Vessells which carry the Stones; they have a lower and upper Deck with two Rail Roads on each Deck paralel with each other and I believe there are seven or Eight Carriages on each Rail Road these Vessells are about 120 Tons Burden but they do not carry above 60 Tons of Stone for if I recollect rightly I calculated that the unnecessary Lumber Rail Roads Carriages, &c. &c. on board was about half the Burden of the Vessell and really the Length of Time in unloading the Vessell beyond all bounds—There are a variety of Ways which occurred to Trevithick and me and which might enable the Contractors to get money by their Contract provided they were allowed to addopt the Method that could be proposed, as it is I am told the Contractors are loosing a great Deal and must continue so to do—on the whole it is the worst conducted Public Work I ever saw.

When I was from home Mr Onions, whom I informed you was making a Steam Wheel at our Foundry, tryed it—It went round I believe several times but the next Day when they attempted to set it to work, it would not Stir and after trying a whole day, they took out one of the Segments and found the Composition Metal or what was used in the Rim as the Resisting Medium, between the Rim and Casing and the Rim split in all the angles, they could not imagine what was the cause of all this, but upon my return home It was mentioned to me when I immediately informed them it proceeded from the fixing or Cooling of the Composition, as this Metal christalizes in cooling and having taken a quantity and melted it, on running it into a Pipe of Cast Iron about 1½ In Dr

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½ Inch thick and 2 feet long, it split it all the way down, and thus confirmed my oppinion.

Since which time they have been imployed in trying different Compositions to endeavour to find one that will not christilize in cooling without Success. Indeed I know of no Composition or Substance that becomes fluid at a low Temperature but what does christilize on Cooling. It is therefore abandoned for the Present.

Mr. Davenport informed me that General Bentham had undertaken the Vauxhall Bridge and I have since heard that it is to be made a Compleat Bridge of Iron for 6 Pounds per Ton. If he has I wish him success and should be happy to render him every Assistance that comes within our Power. I observed that the Rope House at Plymouth was in the same State as immediately after the Fire. Has any Thing more occurred about it?

Is the Cistern you named, about to be done? Have you yet determined any Thing about your Iron work?

Has Laing &c. met any further Encouragement from the Navy Board?

I shall be happy to hear from you as soon as convenient; I have a Many Subjects in the Mechanical way to converse on with you when we Meet—

I am Dr. Sir

Your most devoted Sert.

JOHN U. RASTRICK.

Best Respects to Mrs. G. and Family.

To S. Goodrich, Esq.,

Civil Engineers Office,

Navy Office, London.

This letter shows the means that Rastrick adopted to enlarge his knowledge and widen his experience, not without an eye to business the whole time. The sidelights thrown on engineering work that was going on at the time are interesting. The docket on the letter shows that the engine for Mr. Davenport was intended for his copper mill at Swansea. The engine by Woolf near Marazion was apparently the first one erected by him in Cornwall, whither he had shortly before returned from London.

The steam engine put up by Trevithick at Wheal Prosper in Gwythian, was a plunger pole engine working with an initial pressure of 100 lb. per sp. in.[16] In a letter to Rastrick on January 26th, 1813, Trevithick says: "That new engine you saw near the seaside with me is now lifting forty millions 1 foot high with 1 bushel of coal which is very nearly double the duty that is done by any other engine in the country."[17]

The Plymouth Breakwater[18] mentioned had only been begun the year before,

[16] Life of Trevithick, i., 69, with drawing.
[17] Life, ii., 55.
[18] See Rennie—Account of the Breakwater in Plymouth Sound, 1848.

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John Rennie being the engineer who is here so severely criticised. The Contractors, Messrs. Fox, Williams & Co., were at this time receiving 2s. 9d. per ton for quarrying and depositing the stone. Afterwards this was reduced to 1s. per ton. Perhaps Trevithick may be credited with some of this saving by reason of his invention of quarry drills.[19] The steam wheel mentioned was patented by William Onions of Paulton, Somerset, 23 January, 1812 (No. 3524) and is fully described in the specification: "One mixture I mean to use" *i.e.* the easily fusible alloy mentioned was to consist of 5 parts bismuth, 2 of tin and 3 of lead.

Among the Goodrich papers there are a number of well-executed designs for engines, most of which are docketed "from Mr. Rastrick." Unfortunately not one is dated; in one case the paper is watermarked "1808" so perhaps we are justified in placing them about the same period as the correspondence just mentioned.

The Trevithick engine at this period consisted of a cast iron boiler with a return flue of wrought iron one leg of which contained the grate, the whole being bolted to the boiler front. The cylinder was sunk in the rear end of the boiler and connecting rods from the crosshead returned to a shaft below. In those days of ponderous condensing beam engines, this high pressure engine was a great advance in lightness and portability. A drawing by Rastrick, upon which he styles himself "Civil engineer" of a "Design for a steam boat," dated March 27th, 1813, has been preserved.[20] It is a paddle boat or barge driven by a Trevithick engine. Nothing came of this design, for Rastrick in his evidence on the Liverpool and Manchester Railroad Bill, 1825, said: "I have never had anything to do with steam boats." It looks rather as if it was simply one of Trevithick's schemes; the latter certainly toyed with the subject of steam navigation in 1804 and again in 1815.[21] The first was certainly a paddle wheel project, but by the latter date Trevithick had schemed a screw propeller.

On April 1, 1814 (No. 3799) J. U. Rastrick took out his one and only patent. This was for "a steam engine on a new and improved construction." The patentee says "that the invention need not be particularly described as it will be fully understood on inspecting the Drawing." The latter shows a Trevithick type engine with cylinder in boiler. One is led to the conclusion that this patent was merely taken out so that the firm could continue to be able to apply the word "patent" to their engines after the expiration of Trevithick's patent in 1816.

After September 12th, 1815, Trevithick's letters to Rastrick cease after a hectic period of orders and counterorders for the engines destined for Lima. On this ill-fated expedition, Trevithick embarked on October 16th.

[19] Life, ii., 23, et seq
[20] "Engineer," 1917, ii., 81, 1 fig.
[21] Life, i., 321.

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Rastrick's next important employment was to design and construct a cast iron bridge over the Wye at Chepstow where he had to contend with a tide of 48 feet rise. The centre arch has a span of 112 feet with a rise of 13 feet and the arches on either side are of gradually diminishing spans on the principle known to the Romans for obtaining a graceful effect. The bridge was opened with great ceremony—a programme has been preserved and is illustrated, Plate IX—on July 24, 1816. The bridge still stands as a testimony to Rastrick's skill (Plate X). Some difference arose between Hazeldine and Rastrick over this bridge but what it was we can only guess.[22] As a consequence Rastrick left and joined Mr. William Foster at Stourbridge, under the name of Foster, Rastrick & Co. Here he designed and executed plant for many ironworks in the Midlands and South Wales, notably Chillington Iron Works near Wolverhampton and Shut End near Stourbridge.

In 1822 he took a step that was destined to influence his whole future career, —he accepted the appointment of engineer to the Stratford and Moreton Rail Road Company. This concern was a horse railway of about 16 miles in length between Stratford-on-Avon and Moreton-in-the-Marsh. A MS. note-book[23] still preserved, gives estimates, sketches of bridges, etc., the date ranging from 1822 to 1826. Another MS note-book, the date of which is fixed by an entry under the year 1825, shows how varied was his employment. Estimates are noted for iron roofs, bridges, gas works plant, boilers, window frames, sugar pans, pumps and engines. A table of estimates for colliery plant is as follows:—

	10 h.p.	14 h.p.	18 h.p.
	£	£	£
Engine	420	522	612
Winding machinery	125	149	171

An interesting item is a sketch and description of an "oil gas work at Post Office managed by Mr. Currie made by Messrs. Taylor & Martineau of the Citty Road." Another note is: "Called and saw Mr. Brown's Engine at work at his House at Printing House Square by forming a vacuum by means of the combustion of Gas and atmospheric air." This is followed by a long description. The engine is that patented by Samuel Brown in 1823 and is the earliest real attempt at a gas engine.

A design of about this time was that of the Rastrick boiler (see Plate XI) for reverberatory furnaces, one of the first waste heat boilers known to the authors. It was of the vertical cylindrical type with an egg-ended top. Midway between the top and the bottom four or a less number of side flues led into a central flue communicating with the lower end. Puddling or heating furnaces were arranged radially to the boiler setting. In spite of the fact that the construction was

[22] Life, i., 367, and ii., 66.
[23] In the Goldsmiths Co.'s Economic Library, University of London.

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essentially weak and unsuited for a greater pressure than about 25lb. per sq. in., the boiler held its own in the Black Country for more than half a century; indeed it is not entirely extinct.[24]

Rastrick was now in his forty-fifth year, well known for his sound judgment and wide experience. In anticipation of being called as a witness in support of the Liverpool and Manchester Railway Bill he went to Newcastle in January, 1825, where he met George Stephenson, Nicholas Wood, William Cubitt and other engineers. On the 18th, the party was at Killingworth, and on the 21st at Hetton Collieries; at both places a number of experiments were made which he detailed under cross-examination. On his way home he visited Middleton Colliery, near Leeds, to see Blenkinsop's rack locomotive which he mentions having seen two years earlier.

In April following, Rastrick duly appeared as a witness.[25] It was his first appearance in such a capacity and he was the first engineering witness called. He detailed his experience and knowledge of the subject and in cross-examination by the leading counsel, the well-known Baron Alderson, exhibited such coolness and shrewdness as quite turned the tables on that learned gentleman who was making all the capital he could out of the effect that locomotive engines would produce on horses on the public highway. He had got to know from some source that the base of the chimney frequently became red hot, for those were the days of the single flued boiler. This is how the examination went:—

Q. Is not this tube (meaning the chimney) sometimes red-hot?

A. Yes.

Q. Would not that frighten a horse?

A. I do not think it would, for how is a horse to know it is red-hot?

Q. Then you think that if they were to put a red-hot poker to a horse's nose, he could not know whether it was red-hot or not?

A. If it was put so near as to burn him, he would be frightened at it; but if you were to take a thing painted red, and another red-hot he would not know the difference.

Rastrick expressed the opinion that a horse would be more likely to be frightened by a coach with a number of persons holding up umbrellas, and the guard blowing his horn, than by a locomotive.

Notwithstanding all the efforts of the engineers, the bill was thrown out and it was not till the following session that another bill became law and the railway was proceeded with. Some interesting points that came out in his evidence upon the Liverpool and Manchester Railroad Bill may be mentioned. Rastrick stated that he used a lead rivet—forerunner of the fusible plug—as an effective

[24] Fowler on Boiler Explosions, *Proc. Inst.C.E.*, cxx., 161.

[25] Proceedings of the Committee of the House of Commons on the Liverpool and Manchester Railroad Bill, 1825.

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low-water safeguard in boilers. He also mentioned that it had been the practice although then disused to put a single plate of copper in a boiler one third of the strength of the iron so that the boiler would fail at that point first. The first of these devices is known to be due to Trevithick and probably the second also is his. Rastrick also mentioned that he always put a lock-up safety valve on his boiler.

In 1828 Horatio Allen (1802-1889), agent of the Delaware & Hudson Canal Co. arrived in Liverpool from New York to purchase locomotives for use on the railway 16 miles in length connecting with the canal at Honesdale, Pa. Allen ordered one engine from Robert Stephenson & Co., and three from Foster, Rastrick & Co. Why he chose the latter firm one can hardly imagine because the only locomotive they had made had been the London one of twenty years earlier. Rastrick's design was quite out of date, for speaking broadly, it was a copy of Hedley's " Puffing Billy " of fourteen years previously. We need not go into detail about these locomotives because they are dealt with fully elsewhere.[26]

In 1828-29, Rastrick constructed the Shut End Railway from Kingswinford to the Staffordshire and Worcestershire Canal, a distance of 3⅛ miles. He also built a locomotive for this line named the " Agenoria "—a replica of the " Stourbridge Lion "—with which there was a grand opening ceremony on June 2nd, 1829.[27] The locomotive fulfilled its purpose quite well, as is evidenced by the fact that it remained in use for upwards of 30 years. In 1885 Mr. Job Short reinstated it and Mr. W. O. Foster presented it to the nation; it is preserved in the Science Museum, South Kensington.

As the Liverpool and Manchester Railway approached completion, the Directors had to decide what kind of power was to be employed upon it. No one by this time was in favour of horse haulage for the difficulties experienced on the Stockton and Darlington line with mixed haulage had been very irritating. Needless to state, George Stephenson advocated locomotives but there was a strong party in favour of fixed engines and rope haulage.

In November 17th, 1828, the Directors appointed Mr. Rastrick and Mr. James Walker of Limehouse to proceed to the Newcastle district to ascertain by actual inspection and investigation " the comparative merits of Fixed Engines and Locomotives, as a moving power on Railways, and especially with reference to the Liverpool and Manchester line."[28]

The tour started with Walker's arrival at Stourbridge on January 10th, 1829. On the 12th, the two engineers attended upon the Directors at Liverpool when

[26] See page 64.

[27] A full account appeared in Aris's " Birmingham Gazette," June, 1829. Reproduced in Mech. Mag., XI., 301.

[28] Minutes of the Directors quoted in Warren's " Century of Locomotive Building by Robert Stephenson & Co., 1923," 171.

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written instructions were handed to them. They spent January 13th and 14th on the Liverpool and Manchester line to familiarize themselves with the task before them.[29] On the 15th they visited the Bolton and Leigh Railway where there was an inclined plane. January 16th was spent at Leeds inspecting the Blenkinsop locomotive. From January 17th to 20th they were at Darlington. On January 21st the engineers were at Stockton, going on to Sunderland, where Rastrick sketches a coal staith belonging to Hetton Colliery. The 22nd was devoted to the engines and the railway there. On the 23rd he was at Newcastle writing up his notes. On the 27th he "drove over from Newcastle in a Post Chaise to the Coal Pit at Brunton." Then follows a remarkable amount of data about the Brunton and Shields Railway. On January 28th appears the entry "Killingworth. Went and breakfasted with Mr. Nichs. Wood and then we walked to the Killingworth Rail Road, viewed the engines at the Coal Pits."

The data that Rastrick amassed are amazing. There are some good sketches and the light that some of these have shed on the early history of the locomotive is quite valuable.

Rastrick arrived back at Stourbridge on February 1st or 2nd and set to work at once on his report. Finding that he needed some further information, he wrote to Timothy Hackworth the following letter:[30]

Stourbridge, 3 Feby., 1829.

Mr. Timy. Hackworth.

Sir,

I am now returned home, and as I am now setting to work to consider the subject of the expence of Locomotive Engines and as I am still at a loss for the Expence incurred in keeping the locomotive Engines in repair I will thank you to send me an account of the materials used for the Repairs of your Engines (locomotive) for the last 12 Months, distinguishing each month's expences separately—and any further information you may think proper.

I find Mr. Nich. Wood of Killingworth has had a set of wt. Iron Tires on the 4 feet Cast Iron Wheels of one of their locomotive Engines in wear for 9 months, & I did not perceive any perceptable wear.

Please to send me the No. of each of your Locomotive Engines, with the Men's Names who work them, that I may know how to distinguish the one from the other.

We just had an opertunity of seeing the american Gentleman at Darlington as we came through on our Return.

I understand they tried the Quantity of Coal & Water your Engine consumed in going from Darlington to Stockton—with a Load as well as in

[29] These and subsequent dates are taken from a diary and notebook preserved in the Rastrick Collection already alluded to.

[30] Kindly lent by Mr. R. Young, great-grandson of the engineer.

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returning with the empty Waggons—the[y] counted the Stroke[s] in every Quarter of a mile & took the Time.

I shall be glad if you would send me the particulars of this Experiment, the Coal & Water Consumed. the Speed & Time—& the Number of Loaded Carriages taken down & the Number of empty Carriages brought up, &c., &c., if you have got it.

And any further Information you may choose to favor me with.

I am, Sir,

Your obd. Servt.,

JOHN U. RASTRICK, C.E.

New Sheldon,
near West Auckland,
Durham.

The report was sent in and, along with Mr. Walker's, was submitted to the Directors on March 9th. The engineers did not speak with any certain voice but on the whole they were in favour of fixed engines. To cut the gordian knot, the Directors adopted the sensible suggestion of inviting a competition for locomotives which should fulfil certain conditions. Rastrick, with Nicholas Wood and John Kennedy, were appointed judges. The trial took place at Rainhill with the result that everybody knows.

Rastrick now became deeply immersed in railway engineering, and for the next 20 years there was hardly a line projected or carried through on behalf of which he did not appear professionally either as witness, surveyor or engineer.

In September 1829, he was engineer for the Kenyon and Leigh Railway, a short junction with the Liverpool and Manchester. The specification has been preserved[31] and is probably the earliest one now extant. He was employed in the following year as contractor to the Leeds and Selby Railway. In 1831 he was engaged with George Stephenson in what was then called the Birmingham and Liverpool Railway. There is a quarto notebook full of his calculations and estimates with a sketch of alternative routes. This railway was carried out in 1833 as the Grand Junction Railway after application to Parliament and a lengthened contest. In these and in every subsequent case Rastrick was an advocate of as direct a line as circumstances would permit.

In 1835, the Manchester and Cheshire Junction Railway was brought forward with Rastrick appointed engineer. This was opposed by the promoters of a rival scheme known as the South Union Railway. The contest led to one of the longest and most expensive Parliamentary fights known up to that date, protracted as it was for over two years. The Act was obtained for the original line under the name of the North Staffordshire Railway and the Trent Valley Railway.

[31] In the Goldsmiths' Economic Library.

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Engineering Library

As early as 1836 the aid of Sir John Rennie and of Rastrick was sought by the promoters of a line to Brighton. Guided by his principle, Rastrick advocated the direct but more difficult route through the downs at Merstham rather than the alternative easy route through the Leatherhead Gap. Together, these engineers succeeded in carrying the day. Very heavy work was necessitated in the Merstham, Balcombe and Clayton tunnels. Another big task was the Ouse Viaduct near Cuckfield, a noble structure of 37 brick arches of 30 feet span crossing the river at a maximum elevation of 100 feet. These works were carried out by the autumn of 1840. The Brighton, Lewes and Hastings Railway, 1843-4, in which is the well-known Preston Viaduct of 28 arches, together with extensions from Shoreham to Portsmouth and branches to Horsham, Newhaven, East Grinstead and Epsom, were subsequently carried out by Rastrick alone, so that the system known till recently as the London, Brighton and South Coast Railway, executed at a cost of over £2½ millions, may be said to be very largely a product of Rastrick's brain and remains as the chief monument to his engineering skill.

But this far from exhausts the tale of his labours. He executed the Bolton and Preston Railway, the Gravesend and Rochester (single line on the side of the old canal), the Ambergate and Nottingham, the Boston and Eastern Junction line from the Midland Railway at Colwich to Grantham. Besides these, Rastrick was engaged in many schemes which for various reasons did not reach finality. In 1835 he projected a railway from Stourbridge via Dudley to Birmingham. In 1838, he designed a ship canal from Lewes to Newhaven, a railway from London Bridge to Westminster Bridge known as the South Metropolitan. In 1839 he surveyed the West Cumberland, Furness and Morecambe Railway (not carried out till 1856) In 1840 he surveyed a railway from Stockport to Macclesfield and from Leek to Stoke-on-Trent. In 1841 he was engaged on the East Anglian Railway from Bishop's Stortford to Norwich and Yarmouth. The Lynn and Ely and the Lynn and East Dereham lines were also his. In fact, Sir John Fowler, who served under him, mentions[32] that in 1845, *i.e.*, when the railway mania was approaching its zenith, Rastrick had no less than 17 railways under his direction.

Rastrick possessed a vigorous constitution and great determination of character. He applied himself unremittingly early and late to the consideration of the details of his work and wore out his juniors with his energy. They, however, always looked up to him with the feelings of the greatest respect.

He joined the Institution of Civil Engineers in 1827,[33] he became a Member of the Society of Arts in 1833, and on January 19th, 1837 he was elected a Fellow of the Royal Society.

[32] Mackay, Life of Sir John Fowler, 1900, p. 75.
[33] Memoir, *Proc. Inst.C.E.*, 1856-57, xvi., 128.

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During 1847 he acted as Consulting Engineer to the Brighton Railway at the end of which year he retired from active work to his estate, Sayes Court, near Chertsey, Surrey, which he farmed himself. His intellect was unimpaired when he died on November 1st 1856 in the 77th year of his age. He lies, appropriately enough, in the Cemetery at Brighton under a massive granite monument which overlooks the railway. He married Sarah Jervis of Stourbridge, and had four sons and two daughters. He had a constitutional objection to having his portrait taken, and not even a photograph of him is known to exist. He made use of the following arms which are depicted on his tomb:—

Argent, a chevron gules between three roses of the last, barbed and seeded proper.

Crest, a martlet expanding its wings warlike on a cap of maintenance.

The paper was illustrated by the documents mentioned in the paper, those from the Goodrich Papers having been kindly lent by the Director of the Science Museum. From these the subjects for the blocks, Plates VII to XI, have been selected.[36]

DISCUSSION.

MR. A. TITLEY thought the John Rastrick mentioned as working on the Thames Driftway must be the same as J. U. Rastrick because in another part of Trevithick's *Life*[34] the author says: "Amongst . . . gentlemen who reported on his work were Rennie, Braithwaite and Rastrick, all afterwards eminent in the engineering world." Further, from the same source, he (Mr. Titley) judged that Rastrick was in partnership with Hazeldine certainly as early as 1812[35] as Hazeldine, Rastrick & Co.

MAJOR H. HARDY said that under the old Patent Law the one who filed the application was considered the inventor; hence an importer of an invention from abroad or a manufacturer patenting a workman's invention was legally the inventor. It was true that after the Patent Law Amendment Act of 1851, all this was altered. It followed that even if Meikle had not been the technical inventor of the thrashing machine yet his patent when obtained would have been valid, hence he, the speaker, did not see that Rastrick could have had any case.

MR. JENKINS said that he did not infer from the Rennie letter that had been quoted that the latter was going to contest Meikle's patent but rather that he was going to oppose Rastrick. It was possible that the thrashing machine was at first quite simple and that Meikle originated the drum and beater.

Mr. Trevithick, Mr. Tyas and Mr. Dendy Marshall also spoke. A vote of thanks to the authors was carried by acclamation.

[34] Life, i., 283, *c.f.*, also ii., 87.
[35] Life, i., 352, ii., 52, 62, etc.
[36] The block of Plate IX. has been lent by the Editor of "The Engineer."—Ed.

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MR. DICKINSON, for the authors, in reply thanked the speakers for the points they had made. He would be glad if some Member would take up the subject of the development of the thrashing machine, as it clearly needed further elucidation.

CORRESPONDENCE.

MR. E. W. HULME wrote that an action at law in the King's Bench would be found in the Common Law not in the Chancery Division. He dissented from Major Hardy's statement. Importations from abroad were encouraged, but the rights of the first inventor in this country were secured.

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The Four Locomotives imported into America in 1829 by the Delaware & Hudson Company.

By L. F. Loree, M.Sc.

(Read at Prince Henry's Room, Fleet Street, March 5th, 1924.)

The introduction and first use of the steam locomotive, the chief factor in the growth of commerce and transportation in this country,[1] can be credited to the foresight and vision of two brothers, William and Maurice Wurts, merchants of the City of Philadelphia and the founders of the Delaware and Hudson Company.

These brothers, keen business men, viewing with concern the lack of progress in manufacturing in their home city due to the shortage of fuel for such purposes, began as early as 1814 the exploration of the north-eastern section of their state for deposits of anthracite, which they felt could be found there. William, the younger of the brothers, made his way alone through the Pocono marshes and mountains with no success but, with the firm conviction that these deposits could yet be found, he pressed onward to the Moosic Mountains to the northward. Still unsuccessful, he crossed this range and descended into the valley of the Lackawanna at Ragged Island. There he fell in with one David Nobles, whom he befriended and released from a burden of debt. Nobles, in gratitude to his benefactor led him to where anthracite could be found not only in the beds of streams but on the surface of adjacent land as well. William immediately secured possession of considerable land by purchase through Nobles, and returned to Philadelphia and reported his findings to his elder brother Maurice. They procured supplies and tools for digging the coal, which they sent forward by team to the scene of the discovery of William. This team arrived at the Mountain Inn in Rix's Gap in 1822, the wagon bearing the inscription "Carbondale, 143 miles from Philadelphia on the Lackawanna River, Lucerne County, Penna," which was the name given this location by these brothers, and which it still bears.

The Wurts Brothers had already set out for this spot, and upon the arrival of their supplies immediately constructed a rude log cabin—the first house in Carbondale—and began digging coal, which was found in abundance. This they transported by team to the nearest streams, and thence by arks to Philadelphia. Though but little of their product survived the many wrecks due to collisions with

[1] The Author is referring to the United States of America.

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rocks and boulders in the swollen streams, they were undaunted and undiscouraged; they disposed of the coal, returned to the scene of their labors, and resumed mining. The difficulties encountered and the cost involved in transporting their coal soon convinced them that they could not compete successfully with the Lehigh coal then being sold in Philadelphia, and that they must seek another market. They turned to New York, dependent upon Philadelphia for the scant supply that city could then give, and began immediately to seek a means of transportation for their product. Maurice, the elder brother, traversing the entire distance from the coal bed to the tidewaters of the Hudson River on foot, became convinced that a canal was practicable. Returning to his native city, he procured from the Legislature of Pennsylvania the right to improve the navigation of the river Lackawaxen. Mainly through the efforts of the Wurts Brothers, " the president, managers and company of the Delaware and Hudson Canal Company " was incorporated in New York on April 23, 1823, which acquired from the Wurts brothers their coal property and rights in Pennsylvania. This company constructed a canal from the Hudson River, at Rondout, to the headwaters of the Lackawaxen at the forks of the Dyberry, now Honesdale. From the western terminus of the canal to the coal bed at Carbondale—a distance of 16 miles—a canal was not feasible, as the Moosic Mountains had to be crossed.

The first coal was brought to Honesdale from the coal field by a wagon-team but this method was soon found unsatisfactory, due to almost impassable roads and the excessive cost of haulage. The chief engineer of the company was directed to devise means to eliminate these conditions.

Mr. John B. Jervis, the chief engineer, adopting the view of his predecessor Mr. Benjamin Wright, but enlarging upon it, worked out the plan of a railroad from the terminus of the canal at Honesdale across the mountains to Carbondale. This plan divided the railroad into two parts—inclined planes and levels. On the former the loaded cars were to be raised and the empties lowered by means of chains and ropes driven by stationary steam engines, or by water power located at the head of each plane, and on the latter the track was to be constructed with descending grades on which the loaded cars would run by gravity. For the return movement of the empty cars on these levels it was planned to use locomotives. Following an extensive study of the available information on the steam locomotive which had been but recently put into use in England, and of which favourable and flattering reports had reached this country, Mr. Jervis submitted to the Board of Managers of the Company a full report recommending this plan. This the Board adopted, and sent Mr. Horatio Allen, an assistant engineer in the company's service, to England to study railroad operation there and to contract for iron rails and locomotives.

Mr. Allen, provided with a letter of credit and with instructions from the Chief Engineer, sailed from New York on January 24, 1828, arrived at Liverpool on

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February 15th, and spent some time in a study of steam locomotive operation in England. His observations so convinced him of the practicability of steam locomotive operation that a contract for iron rail was placed on April 15, 1828, with W. and I. Sparrow, of Wolverhampton, and on July 19th of that year Mr. Allen reported to the Managers that he had contracted for four locomotives,—with Robert Stephenson & Company for one, and with Foster, Rastrick & Co. for three.

In a previous letter, dated June 30th, Mr. Allen, explaining the delay in the placing of these contracts, stated that while both Stephenson & Co. and Foster, Rastrick & Co. had assured him that they would have their new engines at work and ready for inspection in the beginning of June, they had failed to do so. He was then able to report that the Stephenson engine for the Bolton railroad would be in Liverpool in a week, also that upon a visit to the works of Foster, Rastrick & Co. he had found that their engine was not yet so far completed as to permit him to form an opinion as to its merits, but that he had arranged to visit their works again on July 7th, when he was to consider their plan and decide upon obtaining one or more from them.

In his letter of July 19th, Mr. Allen, following his report of the contract prices, stated that his original intention was to procure more of the Stephenson locomotives, but the price as well as other circumstances compelled him to purchase from Foster, Rastrick & Co., whose price was £110 less, and his reason for giving Stephenson the higher price for one locomotive was due to the assistance and valuable practical information furnished him by Mr. Stephenson and his son during his investigations.

Writing President Bolton from London on August 15, 1828, on the progress in the construction of these locomotives, Mr. Allen stated that their weight exceeded his wishes, and that while every exertion had been made to reduce the weight, they would probably weigh about six and one-half tons without water, and that the usual weight of the locomotives there was eight to nine tons.

The locomotive built by Robert Stephenson & Company was number 12 on their construction list, and was named "America." This locomotive was completed and shipped from that Company's works at Newcastle-on-Tyne on October 20, 1828, by ship "Young Husband," to London, from London to New York on November 27, 1828, by ship "Columbia," and arrived New York on January 15, 1829. This locomotive was the first to reach America. Its dimensions were: Boiler, diameter 49 inches, length 9 feet 6 inches, cylinders, diameter 9 inches, stroke 24 inches, furnace 48 by 36 inches, drivers 48 inches, tubes, 2, diameter of each 19 inches; which opened directly into the base of the smoke stack, there being no smoke box. The gauge was four feet three inches. This locomotive, which cost the Company delivered in New York $3,663.30, was unloaded and set up on blocks in the yard of Abeel and Dunscomb, Foundrymen, 375, Water Street, New

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York City, where it arrived on May 20, 1829, and demonstrated under steam on May 27, 1829. It was sent up the Hudson River in the "Congress" on July 2, 1829, to Rondout, where it arrived on July 3, and cleared Eddyville on the canal on July 16, 1829. The original plan was to transport this locomotive and the "Stourbridge Lion," which had reached New York on May 13, 1829, to Rondout in two canal boats, which had been sent to New York for that purpose at a cost of fifty dollars. Mr. Jervis, when informed of this intention by President Bolton, advised against it, feeling that the risk of loss or damage to the locomotives was too great. President Bolton thereupon directed Treasurer Flewelling in New York to arrange with the Agent of the "Congress" to take the locomotives on the deck of that steamboat, and tow the two canal boats up at the same time. This was done at a cost of seventy-five dollars, which included, in addition, the freight on 80 pairs of wheels for the railroad cars. No record of the arrival of the "America" at Honesdale has been found, and no mention of it is made in the correspondence relative to the unloading of the "Stourbridge Lion" that has so far been located. A former employee of this Company and later in the service of the Pennsylvania Coal Company, under John B. Smith, for many years Superintendent and later president of that company, stated that Mr. Smith had informed him that, for some reason unknown, the "second locomotive" had been unloaded at Hawley, and never reached Honesdale.

In an attempt to verify this statement, a former canal employee, Mr. Mordecai R. Edwards, now 79 years of age and residing at Hawley, was located, who had heard this story but did not recall the details if he had ever known them. It is, however, certain that one of the cylinders was located in the United States National Museum at Washington by one of the compilers of the history of the Company, and his identification was later verified by Robert Stephenson & Company through the assistance of Mr. H. W. Dickinson, Hon. Sec. of the Society. The iron wheel straps or bands affixed to the spokes between the hubs and tires belonging to this locomotive are also in the Smithsonian Institution, having been sent there as parts of the "Lion" and applied in error to the partial replica of the wheels of that locomotive now set up on the exhibition floor.

The three locomotives built by Foster, Rastrick & Company, of Stourbridge, England, were the "Stourbridge Lion," "Delaware," and "Hudson." They were similar to one another in design, which will appear in the description of the "Stourbridge Lion."

The "Stourbridge Lion" was completed and shipped from Stourbridge to Liverpool in February, 1829, and from Liverpool on April 8, 1829, by ship "John Jay," and reached New York on May 13, 1829. It cost the Company delivered to New York $2,914.90, and was unloaded and taken to the works of William Kemble, the New York Agent of the West Point Foundry, set up on blocks, and demons-

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trated under steam on May 28, 1829. It was sent up the river with the "America" in the "Congress" on July 2, 1829, to Rondout, where it arrived on July 3rd. It cleared Eddyville on the Canal on July 16, 1829, for Honesdale. The exact date of its arrival at Honesdale has not been discovered, but among vouchers included in the accounts of Chief Engineer Jervis for 1829 receipted bills have been found showing charges of Russel Spencer, of Honesdale, under date of July 27, 1829, for "Six pounds ten ounces of iron for capstan to unload locomotive," and on July 30, for "making & repairing sundry irons for steam engine," of Hiram Plum for labor and miscellaneous work for period July 3 to December 31, 1829, "July 24, 8 days work raising and moving engine," 25th, "5½ days work making capstan &c.," 28th, "10½ days work making capstan & unloading engine," and August 3, "3 days work drawing engine & at R.R. Works," of Simeon S. Chamberlin for "3 bushels charcoal for locomotive," the date of which is unfortunately, not given, of David Tarbeau, August 1, for "one leather pipe for locomotive engine," of A. & N. Blood for "10 shieves furnished for unloading Locomotive," "1 pulley block for unloading Locomotive," and "painting waggon for Locomotive tender." The cost of painting the waggon was $2.50, and the dates of these charges are not shown. Also of Patrick McEwing for "2 days in July helping to take engine out of boat," and of Henry Harrington, August 4, for "steam boiler for locomotive." That this boiler was a small one, and perhaps an appurtenance, is evidenced by its cost of four dollars.

President Bolton, writing from Honesdale on July 20th, said that the boats with the locomotives and three others were expected to reach there on the 22nd.

Mr. Jervis, in a letter to Mr. Bolton dated Honesdale, August 5, 1829, stated:

> "We have the "Lion" on the Rail Road, and shall probably put steam on her to-morrow or next day. I shall then inform you of the sense of the experiment. I must confess my anxiety raises as we approach the period when all our different contrivances must come to their touchstone of experiment. I hope well, however, and do not see any particular reason to apprehend difficulties."

It made its trial trip on August 8, 1829. This date, heretofore recorded from newspaper accounts and personal letters of individuals witnessing the experiment, is verified by the report of this trial made by Mr. Jervis to President Bolton dated Honesdale, August 8, 1829, which reads:

> "This morning we put steam on the Locomotive for the first time, & by giving her motion in this way brought the entire strain we have to provide for. The result has led us to the conclusion that our curved road with 15 feet streaches will require additional support. When the streaches are ten feet we think it will do the work we calculated for. We have not had much trial on straight road that has 15 feet streaches, but so far as we had opportunity there is not apparently any important deficiency in strength—not such as to induce us to be-

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lieve there will be any immediate necessity for additional support. I am not able to state the amount of work of this kind that will need additional strength—but the quantity is not great. The engine goes round the curves very well—the difficulty being in the road as above mentioned. The locomotive will, I think, fully answer our expectations, when we get the road firm enough to bear it. So far I think all the difficulties discovered can be easily remedied, though it must necessarily be at some loss of time—which is greatly to be regretted, though unavoidable. I have adopted what appeared in fact the only course (to make every arrangement) in our power to secure those parts of the work that are deficient in strength."

This was the first locomotive operated in the western hemisphere.

Its dimensions were: Boiler, diameter 4 feet, length 10 feet 6 inches, furnace, length 4 feet, cylinders diameter 8¾ inches, stroke 4 feet, drivers 4 feet 1 inch, flues, 2, diameter 17 inches, length 4 feet, gauge 4 feet 3 inches. Some work to strengthen the track for its further use was done, and the locomotive was again run on September 9th. Mr. Allen writing to Samuel Flewelling, Treasurer, from Honesdale, on September 13th, states:

"On Wednesday last we had the engine in motion again, and its operation on the road carefully observed. The railroad as it now stands is not sufficiently stable for the operation of the locomotive. Before it is put to work on it, the road ought to be carefully examined and strengthened, without doing so it would be unsafe to put the engine at work."

Following an explanation of the reason for the weakness of the timber rails as constructed, Mr. Allen recommended that the other levels where the track was on "low work" be strengthened to permit the operation of the locomotives already ordered and the construction of two lighter six horse power locomotives for the "intermediate five miles." This recommendation was not adopted, and the horse path of plank was constructed and put into use.

This locomotive after the second trial was removed from the rails and stored for some time alongside the track. The bill of Jason Torrey, containing a charge under date of October 23, 1829, "For Lumber for covering Steam Engine, 1,863 feet Hem. boards delivered @ 5.50—$10.25," has been found among Mr. Jervis' accounts for 1829. About 1849 it was taken to Carbondale, where the boiler was used in the shop and, as has been stated by employees in the service of the company at that time, many of the parts worked up for other uses. The boiler remained in service in the shop until the 1870's, when it was replaced by another of higher power. It was subsequently sold, and in the late 1880's was located in the foundry yard of Lindsey & Early at Carbondale, and placed "on deposit" by them in the Smithsonian Institution on June 18, 1889. Hope has not been completely abandoned that additional parts may yet be located, and added to those already preserved.

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The second locomotive constructed by Foster, Rastrick & Co., named either the "Delaware" or the "Hudson," which, is not known, was forwarded from Liverpool on June 21, 1829, in the ship "Splendid," and arrived in New York on August 9th, and cost delivered in New York $2,944.40. This locomotive, with the exception of the "cistern" which could not be found in the "Splendid," was loaded on the sloop "Cornelia" on Saturday, September 5th, and left New York for Rondout on September 6th. The cistern was located in the "Splendid" on September 7th, and sent to Rondout in the steamboat "Congress." The articles sent up by the "Cornelia" were "placed into store" on the afternoon of September 22nd.

The third Foster, Rastrick & Co. locomotive, named either the "Hudson" or the "Delaware," which, is not known, was forwarded from Liverpool in the "John Jay" on August 8, 1829, arrived in New York on September 17, 1829, and its cost to the company delivered at New York was $2,992.98. This locomotive, with the exception of the boiler, was sent up the river to Rondout in the "Cornelia" on probably October 3rd or 4th, as per two letters recently discovered, Samuel Flewelling, Treasurer, to B. J. Seward, the Company's agent at Rondout, dated respectively October 2 and 5, 1829, the former:

"The locomotive engine will be sent up by the Cornelia, and consists of the following packages:

No. 20 to 27—8 Boxes
28—1 Boiler
29—1 Chimney
30—2 Axle Trees
31—4 Wheels

and you will please see that all of these items are received,"

and the latter:

"Capt. Goetchies took everything on board on Saturday belonging to the engines, as stated in my letter dated the 2nd, except the boiler. It was after dark on Saturday evening before he got along side of the wharf where it had been landed from the ship, and I was unwilling to run the risk of his taking it on board. Without a great number of men to move it, it appeared to me the frame on which it rests might be materially injured, if nothing worse occurred. I shall send it to Abeel & Dunscomb on a truck, from whence it can be taken by any of the sloops taking coal to them."

The box or case numbers and contents shown above tally with those given in the bill of lading, the policy of insurance on, and the "particulars" or description of the parts in each box of the third and last Foster, Rastrick & Co. locomotive which arrived in the "John Jay."

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The boiler was sent to Rondout in the sloop "Forrester" on October 21, 1829.

In a letter to W. & J. Brown & Co., London, dated June 13, 1829, copy of which we have, Mr. Rastrick writes in explanation of the delay in forwarding this locomotive:

"The last engine would have been sent off last week, but as I have made some very important additions and improvements to our locomotive engine that we started the 2d instant, I determined to alter the one in hand, we are now doing this, and I shall also send the additional parts for the two engines already sent, free of any additional charge, being desirous to make them as perfect as possible, and when I have wrote Mr. Allen, from whom I have had a letter and send him the drawings and details, I know he will feel I have done everything for their advantages, and that the delay of a few months will be amply compensated for by the improvements of the engines. I will send the whole off in ten days."

These improvements consisted of a water heater fitted up with pipes, etc., as per copy of Mr. Rastrick's letter to W. & J. Brown & Co. endorsed on list of the "particulars" of the third locomotive. As this locomotive and the parts did not reach New York until after the two trial runs of the "Lion," it is doubtful whether these new parts were applied.

It is possible that the names of the last two locomotives may yet be definitely determined.

Although not related to this subject it is an interesting fact that prior to the completion of the horse path the cars were moved on the levels by man power. Vouchers for payment of men for "pushing" and "shoving" cars and for board of men so engaged have been recently discovered in Mr. Jervis's accounts.

As the foregoing is the first authentic information obtained that all four of the locomotives reached Rondout, further research in this direction will be undertaken to ascertain, if possible, their final disposition.

The Author, who is the President of the Delaware and Hudson Co., was not able to be present and the paper was read by the Hon. Sec., Mr. Dickinson. After a vote of thanks to the Author was carried by acclamation the

DISCUSSION

was opened by Mr. Dickinson, who said that the Society should be glad to have this paper because it set at rest once and for all the doubt that had existed hitherto as to the number of locomotives that had been sent to America from England in 1829 and which were the first to run on the North American Continent. He had made some search independently on this point and had satisfied himself that Foster, Rastrick and Co., had made three locomotives because Rastrick himself speaking of the spring safety valves that he had designed says that they are "the same as I have put upon three loco-motive Engines I am sending to America."[2]

[2] Report to the Directors of the Liverpool and Manchester Railway, 2nd edition, In the first edition the word "three" does not appear.

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There was not the same assurance, however, about the names of the locomotives. The authority for the name "America" was the appearance of that word against the engine number in Robert Stephenson & Co.'s *Descriptive Book*, 1831, where it might mean no more than that the engine was destined to go to America. As to the "Stourbridge Lion" it would be observed that when Jervis refers to it by name he calls it the "Lion" simply. It is quite likely that the word "Stourbridge" was added afterwards. The names of the remaining locomotives are admittedly uncertain.

It is to be regretted that drawings of these engines are not now to be found but they had a basis to go on because there was not much doubt that the "Agenoria" (1829), now preserved in the Science Museum, South Kensington, was made from the same patterns.

He had found a photograph taken from a drawing supposed to be of the "Lion" but the origin of which was unknown (see Plates XII and XIII); it agreed with the known dimensions, and till something better turned up, it might be accepted.

CORRESPONDENCE.

MR. FORWARD wrote that he was much interested in Mr. Loree's paper. He thought that R. Stephenson & Co.'s prices were probably higher than those of Foster, Rastrick & Co., because they were charging more for their improved design with inclined outside cylinders, as exemplified by the "Lancashire Witch."

He agreed with Mr. Dickinson in thinking that the Stephenson engine was probably unnamed. He would like to ask why the ironwork of the wheels sent to the Washington Museum as parts of the "Lion," were now said to belong to the Stephenson engine. As far as available evidence goes, both engines originally had the same type of wooden wheels. The existing parts of the "Lion" are exactly like the corresponding parts of the "Agenoria," but it is believed that the existing framing and wheels of the latter are replacements. According to the only known illustrations of the "Lion" (see reproduction) is would appear to have had a timber frame of primitive form.

As regards the cistern mentioned in connection with the second Rastrick engine, he believed that there was a statement, made by Allen, to the effect that he had ordered such cisterns to be fitted to the engines in order to avoid having separate water tenders. The above-mentioned illustration shows a cistern under the boiler with a branch from the exhaust steam pipe leading into it for heating the water. This is mentioned by Rastrick as an improvement added to the third engine after being applied to the "Agenoria."

It is certainly to be hoped that further parts of these engines will be found, which is not at all improbable, as in the case of Ericsson's "Novelty" of 1829, the original cylinders were discovered in 1904 and the wheels in 1914.

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Works Organization in the Seventeenth Century.

Some Account of Ambrose and John Crowley,

By W. A. Young.

(Read at Prince Henry's Room, Fleet Street, April 12th, 1924.)

At the close of the seventeenth century a man of forty years of age—now nearly forgotten although he became a prominent figure in the London of Queen Anne—was trading in Thames Street, London, and at Greenwich. This man was Ambrose Crowley who, rising from complete obscurity, built up in London and in the county of Durham, aided by his son John, a manufacturing business which was probably the biggest of its kind in this country and certainly unique in its organization.

What the nature of the business was is well described in an advertisement which appeared in 1698.[1]

> "Mr. Crowley at the Doublet in Thames-street, London, Ironmonger, doth hereby give Notice, that at his Works at Winlaton, near Newcastle upon Tine, any good Workmen that can make the following Goods shall have constant imployment, and their Wages every Week punctually paid, *viz.*, Augers, Bed-screws, Box and Sad-Irons, Chains, Edge Tools, Files, Hammers, Hinges, Hows for the Plantations, Locks especially Sto Locks, Nailes, Patten-Rings, and almost all other sorts of Smith's Ware."

That the business was very lucrative is shown by the fact that when Sir Ambrose Crowley (for he was knighted in 1707) died at the comparatively early age of 54 he had amassed a fortune of at least £100,000.

The organization at Winlaton was that of a community the members of which voluntarily submitted themselves to a code of laws instituted by Crowley, but the carrying out of which was delegated to a court of arbitration largely composed of the men themselves. Medical attention, sick benefit, superannuation, education for the children, and provision for dependents on the disablement or death of the worker were all provided for under the scheme.

The organization did not, of course, grow up at once but it was remarkably well conceived and its vitality is shown by the fact that it lasted well on into the nineteenth century.

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[1] *Post Boy*, July 28-30, 1698.

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First of all, a few words as to the origin and history of the Crowleys. As has been stated above, he received the honour of Knighthood when as one of the Sheriffs of the City of London he attended upon the Queen at St. James's Palace in January 1706-7. In the pedigree lodged by the grantee when applying subsequently for a coat of arms, he stated that he was " the son of Ambrose Crowley of Sturbridge in the County of Worcester." Le Neve adds the information that he was " No gent or any pretence to arms, a quaker living in 1708."[2] The Church Registers of Rowley Regis, Staffs., show that one Ambrose Crowley, Crawley or Croley, a nailer, had children baptised in the church and also buried some of them in the churchyard during the middle part of the 17th century. It is highly probable that Ambrose was born in this parish, the year of his birth being 1659.

Ambrose Crowley in all probability followed his father's trade, indeed the Doublet, which was his sign, is stated to have been a representation of the leather jerkin which he wore when working as a smith. If he were apprenticed to the trade he would not be out of his time till 1680. Nothing is known of his activities, however, till 1682 when it is stated[3] that he was carrying on an ironmongery business at Greenwich, and that he started a works at Sunderland about that date. It is six years later before we definitely hear of him in London and by that time he was employing 100 men at Sunderland. This appears from a petition to the King[4]:—

Ambrose Crowley.

Upon the Petition of Ambrose Crowley Ironmonger of London praying his Maj^{ty} to order that the Cathock and other Workemen which he shall employ in the Factory he hath set up in Sunderland in the County of Durham for making Iron ware may as quietly enjoy their Religion and be not molested as Protestant Strangers, or as the English do.

At the Court of Whitehall July 2d. 1688.

His Maj^{ty} being graciously disposed to give the Pet^{n} all fitting encouragement is pleased to referre this Petition to Mr. Atturney Generall to consider thereof and report what his Maj^{ty} may fitly do in the matter, whereupon his Maj^{ty} will declare his further pleasure.

Sunderland P.

At the Court at Whitehall the sixth day of July, 1688.[5]

Persons imployed by Ambrose Crowley in a Manufactory not to be molested.

Upon reading the Petition of Ambrose Crowley of London Ironmonger Setting forth that he hath erected at Sunderland a Factory for making of Iron Ware, where he Imploys at present about one hundred men, Severall

[2] Le Neve, Pedigree of the Knights Charles II. to Queen Anne.—Harl. Soc. Pub. VIII., 1873.
[3] Victoria County Histories.—Durham, ii., 282, et seq.
[4] State Pap. Dom. Entry Bk., 236, p. 24.
[5] Privy Council Papers, P.C., 2/72

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of whom came from Liege; And that he designes to Imploy three or four hundred men more in the said Factory. That the Persons already imployed by the Pet^r. have taught the English workmen there to work better and Swifter then formerly, and to make such nailes as are used in Holland for Sheathing of Shipps. Wherefore humbly praying that his workemen may not be Molested on account of their Religion or otherwise, As in the Petition a Copy whereof is hereunto annexed, is more at large exprest. And upon reading a Report of his Ma^tys Atturny Generall to whom the same was Referred, And due Consideration had thereof, His Ma^ty in Councill is graciously pleased to Order, And it is hereby Ordered that the Rt. Reverend Father in God the Lord Bishop of Durham, do take speedy and effectual care that the Petitioners Workemen be protected and quieted in their carrying on the manufacture in the said Petition mentioned; And that his Lo^p do signify this his Ma^tys pleasure to the Justices of the Peace in the Neighborhood where the Pet^rs workemen Reside, to the end the same may be observed by them accordingly.

It is more than likely that the Lord Bishop failed to ensure peace between the Catholic and Protestant workmen, and Sunderland probably paid scant attention to the finding of the Privy Council, for two years after the promulgation of the order Crowley migrated to Swalwell. There he opened works on the River Derwent, and at a later date founded a second works at Winlaton, where two mills were set up for the slitting of iron.

After this, the rise of Ambrose Crowley to importance and wealth was rapid. He was common Councillor for Dowgate Ward from 1697 until 1711, when he was elected Alderman of Greenhithe Ward.[6] He was as we have seen Sheriff in 1706-7, and but for his early death he might have reached the Chair. He was free of the Drapers Company,[7] which he served as Master in 1708. He became an original director of the South Sea Company in 1711,[8] succeeding in August, 1712, Sir Samuel Ongley, a Cornhill linendraper, as Deputy Governor. Sir Ambrose was elected Member of Parliament for Andover in 1713; but his career was cut short by his death in October of that year.

He was buried at Mitcham, Surrey, where in the Parish Church, on the N. wall of the baptistery there is a marble monument exhibiting the conjugate heads of a man and a woman with a coat of arms now indecipherable, and this inscription:—

"Near this place are deposited the Remains of Sr Ambrofe Crowley Knight Citizen and Alderman of London, whofe numerous Family and great Estate were the prefent rewards of an indefatigable Industry & Application to Bufinefs

[6] Beaden, *Aldermen of the City of London*, 1908.
[7] It might have been expected that he would have belonged to the Ironmongers' Co.
[8] Melville, *The South Sea Bubble*, 1921.

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an unblemished Probity, and a fincere belief and Practice of true Christianity,
and particularly a boundless Liberality towards the Poor,
many Hundreds of whom he continually employd
Neare him lies ye Body of Dame Mary his Wife, ye Daughter of Charles Owen, Esqr,
a Younger Son of ye family of Condor. fhe buried feven Children Infants
and faw one Son John Crowley Esqr and five Daughters married.
John was married to Theodofia Gafcoign of Enfield. Mary to James Hallett Esqr
of Efsex. Lettice to Sr John Hind Cotton of Cambridg-fhire Bar^t.
Sarah to Humphrey Parfons Esqr of Surry. Anna to Richard Fleming of Hants,
and Elizabeth to the Right Honble Lord St. John of Bletsoe.
Sr Ambrofe died Octr 7th, 1713, Aged 54 Years.
His Lady in the 63^d Year of her Age, 1727."

There is nothing in the Mitcham burial registers to show the place of residence either of Sir Ambrose or of Dame Mary at the time of their death. It is stated that Sir Ambrose never lived in Mitcham but that his body and that of his wife were brought from Greenwich and buried beneath the North Chapel which was then in the possession of one Francis Knight, of Hall Place, Mitcham, whose daughter married Ambrose Crowley[9] (presumably the grandson).

By his will, Sir Ambrose bequeathed to his son John (born Nov. 3rd, 1689):

"Land, tenements, buildings, shops, houses, warehouses, mills, fforges, and hereditaments. freehold and leasehold in the Counties and Bishopricks of Durham & Worcestershire and the County of Kent."

The will is that of an immensely rich man, worth at least £100,000. Dame Crowley was to have an annuity of £100 a year and £24,000 (£16,000 in South Sea Stock and £8,000 in "tallys on Her Majesties Exchequer or in bonds or other securities). Provision was made also for Mary, married to James Hallett and her children, while to the four unmarried girls the testators bequeathed £10,000 apiece on attaining the age of 25 years, or at marriage, if the match was approved by the mother and brother. To provide for these payments the executors were to lodge with the Master, Warden & Company of Drapers £28,000 in South Sea Stock and £12,000 in good bonds and other security, his son's bond for £6,000 to be taken as such security. John Hanmer, if in the employ of the firm at the time of the testator's death, was to have £50 a year over his salary as long as he continued to serve John Crowley. If John Crowley died without issue it was his father's wish that he should "dispose and Grant four thousand pounds to my children and Family."

John Crowley had two sons, Ambrose and John,[10] both of whom died without issue. He had four daughters of whom Elizabeth, the second, alone finds a place

[9] Communicated through the Rev. C. A. Finch, the present incumbent of the parish.
[10] Surtees, History and Antiquities of the County Palatine of Durham, ii., 1816.

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in this story. She married the second Earl of Ashburnham, and when her mother, Theodosia Crowley, having survived all her children, died in 1782, she devised her property, for she had been an heiress in her own right, to the Earl and his only son George, Viscount St. Asaph, and his sisters. It is worthy of remark that in this way part of a fortune made by one of the earliest of the great ironmasters of the North passed to the family of the last of the ironmasters in Sussex.

John Crowley was Common Councillor for Dowgate Ward from 1721-27 when he was raised to the Aldermanic bench. He was Member of Parliament for Okehampton 1722-27.

John Crowley, by will dated May 16th, 1726,[11] two years before his death at the early age of 39, left to his son, Ambrose, real estate in Greenwich and Thames Street, and half a dozen villages in Suffolk, Surrey and Essex. No reference is made to the Durham property, although there is a specific bequest of the "Aldusford fforge in the County of Northumberland." Theodosia Crowley and her brother, Joseph Gascoigne Nightingale, or the survivor, with Sir Gregory Page were "to carry on and manage my trade and business or such branches as are most beneficial" until Ambrose Crowley came of age. To further that end, John Crowley's will was that his trusty servant John Hanmer should have £400 a year, and be empowered to appoint three others to assist him in the management, each at £50 additional salary. Hanmer was to render accounts periodically to the executors and Sir Gregory Page. There was a clause under which, in certain contingencies, Hanmer might nominate his successor.

A study of the Essayists often sheds light on the men and women of the reigns of Queen Anne and the First George. The thin disguises of *The Spectator* and of *The Tatler* have been penetrated by annotators and real persons have emerged from the pages of those famous journals. No. 299 of *The Spectator*[12] contains an amusing letter, to which is appended the signature of John Enville Knt, who complains that one woman and a fortune have driven him to abandon his birth name. From being Jack Anvil, "a person of no extraction (who) began the world with a small parcel of rusty iron," he had accumulated at twenty-five £4,200, and ten years later had made "a very large fortune" and won the honour of knighthood. His lady, not caring to be known as the wife of Sir John Anvil, stipulated for a more distinguished cognomen—and had decided upon Enville. This shaft, according to the annotators, was aimed at Sir Ambrose Crowley, who was also satirised in a skit, on an aldermanic election, written by Steel for *The Tatler*.[13] It matters little now which of the rival candidates was meant for

[11] P.C.C. 6 Brook.
[12] Feb. 12th, 1712.
[13] No. 73, Sept. 26, 1709.

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Crowley, but Mr. Urban, writing later on the subject in the "*Gentleman's Magazine*,"[14] has a footnote that is not unimportant, inasmuch as it mentions that:

"Sir A. Crowley was perhaps one of the first who circulated notes instead of money, in several towns and villages where he dwelt, from two pence to twenty shillings."

Dean Swift[15] confirms this fact about Crowley who is also mentioned in the third *Drapier Letter*, dated Aug. 24, 1724, and William Penn has left it on record that he consulted Ambrose Crowley about the development of the iron industry in Pennsylvania.[16] Another reference to the family may be found in the *Gentleman's Magazine*,[17] where, in a letter bearing the signature *I.M.*, Crowley is described as "This ironmonger (the greatest manufacturer of ironware in Europe)." The writer of that letter is almost certainly Isaac Millington, who became Theodosia Crowley's partner after John Crowley's death. The style of the firm then became Crowley & Millington, and there is reason to believe that it was altered again to Crowley, Millington & Co. Efforts to find when the business was finally closed down have failed, but it is possible that it lasted until the middle of the last century.

The Works and their Organization.

We now turn to the consideration of the works, their history and organization. Surtees writing in 1816[18] says of Sir Ambrose Crowley:

"He first sat down at Sunderland but was induced to remove his colony to Winlaton from the advantages of the situation betwixt the Tyne and the Derwent, a cheaper country and plenty of coal. The establishment extends to Swalwell."

Of the latter village he says it

"is almost entirely occupied by the ironworks, first established here about 1690 by Sir Ambrose Crowley. . . . Anchors and other articles of the most massive kind are manufactured here, besides hoes, shovels, &c. for country use."

Surtees gives 1690 as the date of the establishment of both works but the best opinion is that Swalwell was the earlier.

Another writes[19] states that the chief branches of work carried on at Winlaton and Winlaton Mills were the making and grinding of edge tools, the manufacture of files, and the slitting of iron bars into nail rods, and continues:

"The works at Swalwell are on a great scale: Anchors of the largest size, mooring chains, pumps and cylinders for steam engines, all kinds of cast metal utensils, agricultural implements, hoes, spades, shovels &c. and in short almost every form of which iron and steel is susceptible, is produced in these works.

[14] Vol. 73, p. 1004.
[15] The Intelligencer, No. XIX., 1729.
[16] J. M. Swank, Iron in All Ages, 1884, Chap. XI.
[17] Vol. 63, p. 237.
[18] Surtees, *op. cit.*, 246 and 272-3.
[19] *Picture of Newcastle*, 1807, 159.

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There is a warehouse of articles for country consumption at Swalwell. The Company has also warehouses at Greenwich and in Thames Street, London. Two vessels of three hundred tons burthen are constantly employed in the carrying trade."

Surtees states further:[20]

"After the works were brought to answer the proprietors view, a code of laws was instituted for the preservation of good order, and a court of arbitration was held every ten weeks to determine disputes and appeals. Schools were established at Winlaton Mill, and Swalwell where the workmen's children were taught reading, writing and accounts. A surgeon was also appointed to attend the whole body; when any workman was ill he had money advanced; when superannuated or disabled, he had a weekly maintenance, and at his death his family were provided for."

Surtees states that these charities all ceased in 1816 and the workmen "are now on the usual footing of other manufacturers."

Further in one of his numerous footnotes he states that:

"Sir Ambrose's descendants sold their interest about 17... to — Millington, whose son, Crawley Millington, is now head of the firm."

It is to be regretted that this well-informed writer should have been unable to fill in the date.

The Crowley Manuscripts.

It is not known whether Surtees was doing more than commit to writing the tradition of the countryside or whether he had documents. It is more than probable that there was a great quantity in existence at the time that he wrote, but all that are at present known are two in number—the Winlaton Law Book of the Iron Mills XVI to XIX centuries—preserved in the British Museum[21] and the Crowley MS. in the Newcastle-on-Tyne Public Library.[22] This contains the Accounts and Proceedings of the Court of Arbitration between the years 1806 and 1843.

To take the earlier MS. first, we find at the outset that the laws and orders set forth in the volume relate as we should expect to the administration of the works;

[20] *Op. cit.*, 443.

[21] Add MSS. 34, 555, acquired 1894. There are 382 pp. bound in a volume 14½in. by 9½in. Each page is closely faint ruled in red ink, with a wide margin on the left-hand side. The writing throughout is in many hands, and only a few of the entries are dated. Reference to the contents is facilitated by an index at each end. On an inserted end paper two manuscript letters are attached, both written from Winlaton and signed by Ambrose Crowley. The dates are November 13, 1702, and December 1, 1702. Among other matters the writer informs Sir William Bowes, Bart., at the House of Commons, of the loss of a ship ladened with 100 tons of iron. It appears also that at the time Crowley was negotiating for the wood in Sir William's haugh and elsewhere, and that he would use it for making charcoal. Crowley agreed also that his servants should not destroy any salmon in the waters adjacent to the wood.

[22] Acquired in 1894. It comprises about 250 pp., close ruled, bound in a volume 11in. by 7½in. A preface by Robert Flower, dated 1894, has been inserted summarising much of the foregoing information.

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only incidentally are there references which are of technical interest. The more closely the laws are studied the more one realises what exceptional men the Crowleys were; men not afraid to delegate power to a comparatively illiterate staff: men who dared to, and did, take risks: men who knew how to reduce detail to a system for others.

As it is impossible to review the Winlaton Laws in a single paper, it must suffice to consider a few of the more important of them. Each is divided into "verses," or as they would now be called clauses or sub-sections. No. 1 Law,[24] entitled "Proof Spy upon the Mill Clerks" is typical. It lays down a system of stock-keeping designed to check "Carelessness in some Clerks and Knavery in others . . . (which) Clouded the Actions of the frugall and Diligent." Specimen rulings were furnished to show how the stock was to be entered, and among the figures recorded are:—

Barr Iron. Tons	19	2	3	19
Rod Iron	17	10	2	19
Strong Hoops	21	5	2	4

The table of stock amounted in all to Tons 75. 15. 3.06. "neat barrs." The regulations were not to be taken as a "President when I shall farm out the Mill"; and one verse provides that:—

"When the charge per Tunn shall Exceed what is here mentioned, the Clerk is to Assign his reasons at large for the same, viz.:—

Wages ..... 5s.

	Cwt.	Q.	lb.	oz.
The produce of Rods Cut	19	—	10	—
Candles to Exceed	—	—	—	—
Grease to Exceed	—	—	1	—
Soap to Exeed	—	—	—	4

It was further provided that the Clerks were "every Day to Pick and Lock up all Bushell Iron, Crop Ends, Mill Parings, and any other Iron whatever that is not then usefull."

The efficient conduct of the two Mills is the subject of several Laws. No. 9,[25] dealing with Iron slitting, embodies a table of rod sizes and twelve tables of Iron barrs, with the number of rods each barr should make if passed through any of the twelve Cutters.

There is little of a technical character in the MS.; but Law No. 28 affords an idea of the lighter work produced in the shops.[26] A specimen schedule of stock contains the following items:—

[24] B.M. MS., *Op. cit.*
[25] *Ibid.*
[26] *Ibid.*

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Parcell.	Cask.	Sorts.	Price	lb.	oz.
	8312.	24 doz. tinn'd latches	3/6 doz.		
		12 doz. Crooked Spring Bolts...	2/6 doz.		
		43 doz. streight do.			
		1 pair Trace Chaines	6/6 doz.		
		2 doz. ½ In. Augr Bitts	7/- doz.		

Take again the bundling of Iron,[27] the details cover the weight of the bundle, the number of bands, and how short ends are to be mixed into the nailers bundles; but all to be of one size. Iron for London is to be 84 lbs. to the bundle, to be straight, tied with three bands, the ends of which were to be knocked down so as not to "Hinder close stowing at London, where room is scarce." A wooden Tally was to be "put fast in every bundle for London."

Nothing escaped the attention of the Crowleys. Rules[28] for the giving out of Tools to workmen had been abused, as upon consideration of the Indigencies of Workmen at their first coming into the Works, Mr. Crowley did trust several with Stock of Tooles to remain in their hands as Stock without Consideration. Fresh regulations were then made, providing that all Tooles to the value of Eight shillings or under shall be charged to the Wardkeeper, and by him sold to the Workmen.

Anvils to be kept in good order, or Ground and Batter'd at the Workmens charge; but when they want Steeling or Large repair it was to be done at Mr. Crowley's charge. But Nailers that work Single or Double hand and Desire Anvils, they are to pay for Steeling or other Repairs. All Bellows to be new Leather'd and piped at Mr. Crowley's charge; but each man was to brush, clean and hook up his bellows every night and oyle them once a year at Workmens charge. Commtee to be judges of Damage of Tools; and James Lamb a Toolkeeper was stigmatised as "Notoriously negligent in Suffering the Pipes of Bellows . . . to be burnt by letting the Workmen keep bad Tuirons."

It is difficult to piece together the Laws made from time to time for the better organisation and management of the works. Law No. 44 opens with a statement[29] that Mill No. 1 had increased in size, and John Crowley "being Desirous as much as in me Lyeth to settle my Affairs to the Ease and Tranquility of my Workmen," ordered under "my Councill at Swalwell, a Committee of such persons as I shall Nominate and appoint to Govern my Mill affairs, to whom I shall give Suitable Directions. They are to Protest and Declare (themselves) to be ffaithfully true and Just to John Crowley, Esqre., and his successors, and their Secrets faithfully keep. "Every morning at nine o'Clock to be a grand Commtee (and) there are to be other Committees as often as emergency of Business may Require." Powers and duties of the Commtees fully stated.

[27] *Ibid*, Law 39.
[28] *Ibid*, Law 54.
[29] *Ibid*.

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The next Law[30] directs attention to great Damages by reason of " unskilfull, negligent and Corrupt Surveyors who (without regard to the great trust reposed in them) have not taken that due Care to prevent errors in the making of Goods." A Surveyor ought to be ready in the knowledge of all Forms belonging to Ware and good Workmanship, so that he may make every Workman rightly understand what he is to make. This new Order gave each Surveyor the power if a Workman " shall vary from the pattern to mulct him the full Damage; " the Surveyor also to compare New Orders, Patterns, Directions, or Instructions, with Old Orders, Patterns, etc., and give his opinion how it may be mended. He was to go among the Workmen and direct them; but must be prudent and abstain from fault finding without cause. It was competent for him to destroy unsaleable Wares, and he was not to spare the Workmen, but when they run into error and " he cannot by any means prevent it, he must do it with regret and pity and never reflect or glory in it."

As[31] " my people at Winlaton had for some time suffered to very great Degree by the ill quality of some Clerks, and Reckoning to make them a happy and flourishing people . . . I commit the Administration to five persons to be termed Arbitrators that in my absence shall hear and determine all petty differences . . . amongst my Workmen." This decision to arbitrate disputes was come to in March, 1724, and, as the sequel proved, this form of management outlasted other expedients tried by John Crowley. The Chaplain (for the time) was always to be first Arbitrator: Crowley named and appointed two, and the other two were elected by " Each Workman that hath given bond and is allowed a Stock of Iron, and pays to the Poor Box at Winlaton." " Every jest or joque " calculated to demean the Council's dignity to cost the perpetrator one penny.

Even more delightful is the Order[32] which appoints a Monitor. It opens with a pleasant discourse upon the " Parable in the Gospel that it is Entirely in the Masters' Pleasure to pay him as much that cometh at the eleventh hour as he that came at the sixth hour." . . . As " Sundry I have Imployed by the Day . . . have pretended a sort of Right to Loyter," (and) " To the end that Sloath and Villany . . . should be detected, I have thought (it) meet to Create an Account of Time by a Monitor." This meant the institution of a system of time keeping based on eighty neat hours service per week, exclusive of all deductions for meals, taverns, etc., etc. The Rules and Regulations outlined in the Order run to 37 verses, or 7 folio sheets.

An early date mentioned in the MS.[33] is 1686. Ambrose Crowley had " found that Sundry People I had trusted with Cash for want of Proving the same which

[30] *Ibid*, Law 45.
[31] *Ibid*, Law 49.
[32] *Ibid*, Order 103.
[33] *Ibid*, Law 21.

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gave opportunity to Villains to make use of my Money, I did then make Orders for the exact Proving of Every Persons' Cash which hath been practised at the Doublett much to my Satisfaction and the Cashkeeper's Safety and Reputation." After naming certain "Designing Villains," he Ordered that every night when all business was over the Cashier was to produce all his Cash, Currant Bills, and all other Accounts whatever to the Examinor the Councill shall appoint according to a "President," or form, which he gives for guidance.

Two specimen forms[35] may be regarded as the equivalents of our Bills of Lading. The first example indicates the way "Wares" were stowed in keels bound for London. It is abstracted from a "President" of the notes that were to be handed to the Skipper:—

			T.	C.	Q.	lbs.
	Winlaton.	Goods as per note	15	—	—	—
Goods for London: In Acct. 1352.	Mill No. 1	Blister'd	02	—	—	—
		Draw'd Steel	02	04	—	—
		Rodd	01	—	—	—
	Mill No. 1	Odd Ware	02	6	—	—
		Rodd Iron	04	—	—	—
	Mill No. 2	Anchors	05	—	—	—
		Hoops	04	—	—	—
		Odd Ware	07	—	—	—
			43	—	—	—

The second "President," though less in tonnage, discloses an interesting increase in the variety of the manufactures shipped by the Crowleys, as follows:—

I herewith send you by Wm. Johnson, Skipper, one keel, containing the undermentioned particulars, viz.:—

	T.	C.	Q.	lbs.
250 Baggs of Nailes, qt	12	10	—	—
5 Casks containing by computation...	01	07	—	—
5 Whole Faggots Steel: Quality No. 3 5 Whole Faggots Steel: Quality No. 4	10	2	—	—
5½ ffaggots Steel: Quality No. 5	02	2	—	—
15 Bundles Strong Hoops: Mill No. 2	10	2	—	—
30 Bundles Slight Hoops: Mill No. 1	11	2	—	—
10 Bundles Rod Steel, 30 lbs. each ...	02	2	—	—
30 Whole Barrs Raw Steel, ...	04	1	—	—
8 Barrs Iron 4 In' Broad ½ In' thick Made at Mill No. 1	02	1	—	—
120 Bundles Rod Iron, 56 lbs. each	03	—	—	—
52 Bundles Rod Iron, 84 lbs. each	01	09	—	—
525	31	—	—	—

A third "President" relates to a similar consignment of 525 Baggs.

[35] *Ibid*, Law 46.

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Keels to be filled up with as many chaldrons of Coal as may be; but shipping office must " first learn what prices Coales bear at London." Particular attention is directed to Loading: to Stowage of Anchors and Raw Steel; while Frying Panns are to be stowed bottom upwards.

Apart from references to the Mills at Winlaton, the expression " The Square " occurs over and over again; but nowhere is there a description (or even a vague indication) of what was perhaps the centre of the community. Whether it was a group of houses, or a number of small shops occupied by outworkers is doubtful; but[36] " Every Thursday in the 7th week between the hours of 7 and 8 in the morning, the Council is to deliver out Tickets for Coals at the Low Rate, and at no other time without a Special Order by me." The Accountant is to enter a Title (or Coal Ticket) to all persons that shall live or work in the Lordship of Winlaton, or at Stella. The Council to allow for every house fire one fother: for every Hearth two fothers, and in certain cases double the Quantity of Tickets or more. That was independent of supplies for " The Square," or the Mills; and perhaps it is a fair inference that " The Square " was surrounded by small forges. (For) " What Coals shall be wanted for the Square, the Tickets must be delivered to the Toolkeeper; and on the Backside of each wrote in a full and deep hand, under the Title of Coals: In James Lamb's hds. P.1 Dr. Those that fill up Tickets must always write the word squa: and Mill."

According to another preamble,[37] great loss had been occasioned " by the great carelessness of former Managers of Coals." All Coals and Contingents relating thereto to be brought into the Square under Title of Coals in Marmaduke Burton's hands. Minute instructions given (to him) about the storage of supplies. Here is form from Coalkeeper's Book for delivering Coal out of the Square:—

Name.	No.	Fothers.	Allowed by Council, fothers.
Paul Matthews	974	1	1
Tho. Hadon	23	2	1
Danel. Luckack	566	1	0

Three names out of seven.

There are other entries; but the foregoing suffices to illustrate verse 13, while verse 16 shows it worked out when the Coalkeeper came to " Enter the Coal ":—

No.	To whom.	Fothers.	When delivered.	By whom	Leading
1.	Paul Matthews	1	October ye 14.	Rixon for Sr.	3d.
4.	Thos. Hadon	1	Do.	A. Crawley	3d.

[36] *Ibid*, Law 73.
[37] *Ibid*, Law 74.

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An idea of the quantity consumed in the Square is revealed in verse 5, which recites that between November 1, 1708, and the last day of February next ensuing, 607 fothers were brought into the Square at a time when "leading from the pits was at an extravagant price." There were very few or no stocks at the first day of November, and the whole work was supply'd from the stock in the Square, so as not to leave "a dead stock to Lye on our hands."

The MS.[38] affords evidence that the Workmen dwelt in houses owned by John Crowley, also that the firm assumed the responsibility for the rent of houses owned by Lord Widrinton and others. A "President" enumerates 5¼d., 6d. and 6½d. as weekly rents, and the annual rent of William Hill's house and shop is put at £3.

The MS.[39] also indicates that Crowley carried on a farm, or farms (whether for his own pleasure or benefit or that of his Works is not stated); but he speaks of "such grounds as I farm in the Bishoprick of Durham." He regularly employed a Husbandman, a Wainman, Haymakers, and a Smith by the year, whose duties are all clearly indicated. A bull was also kept.

The Crowleys and Welfare Work.

A proportion of the laws and orders dealt with what would now be called welfare work. For the assessment of the poor, Crowley ordains[40] that cases of hardship are to be considered at a Court of Government to be held every eighth week. Nine Governors are to form a unit (? quorum). When there were no extraordinary calls upon the poor fund

> We'll design to make but a half assessment yt is but one-eighth part of a penny upon every shilling in wages . . . then he that earneth 11¾d. pays nothing . . . from 1s. to 2s. 11¾d. pays ¼d."

The scale rises by small graduations until the levy stands at 5d. for men earning 40s. a week. Sir Ambrose's quota was based on a per lb. rating but how the amount to be contributed was reached is not clear. For the Hammer men the levy was "two pence per week, neither more nor less."

Good Government is the comprehensive title of another law[41] running into 75 verses, and condemning *inter alia* treason, murder, abusive language, nastiness, gaming and "clubbing for drink within the square above the value of twopence in three hours space." With the best of intentions, good government as ordained in London did not always ensure good conduct in Co. Durham, and an order "Extravagancies,"[42] had to be issued instructing the treasurer "to make it his business to pry and enquire into the action of all Clerks whatever and if he findeth

[38] *Ibid*, Law 61.
[39] *Ibid*, Law 68.
[40] *Ibid*, Law 8.
[41] *Ibid*, Law 53.
[42] *Ibid*, Order 85.

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any guilty of the said vices . . . to inform me." Certain culprits are named, Benjamin Lee and Richard Collins for " whoreing," Humphrey Vincent for pride and high eating, Samuel Barker for gaming, William Junning for sotting and trading, and all of them for confederacy to the hurt of the business. Particularly the treasurer was to watch those who lived beyond their means or go " much abroad particularly to Newcastle, which hath been the ruin of several." The last verse is directed against morning drinking, a habit which John Crowley views seriously and " hath totally broke it in London even to go and drink in the morning with customers, and hath found the same to be obligeing and not offensive to the best of customers." Disregard of this order was to be visited by dismissal.

The laying of information[43] against a fellow workman was not regarded in the light of sneaking. Indeed it was encouraged as " a good and necessary office," and if an irregularity was detected by that means, and the offender was mulcted in a fine it was divided between the informer and the poor fund. The informer was protected if he puts a mark like a heart " on the back-side, near the seal of the letter he sendeth me, and then no person will open the letter but myself." Those who lodged an idle tale, however, were liable to be mulcted in one shilling. The very last order[44] of all comes under the category of social welfare, and bears the date 1724. John Crowley having considered the deplorable state of his " honest and Laborious workmen and their families " is resolved to appoint " one well skilled in Physick . . . one that's of a sober life and conversation and not addicted so much to pleasures as to be withdrawn from a due attendance on his business." The person appointed is hedged about with many restrictions on his liberty, but he has some privileges. His patients are encouraged to inform against him if they suspect him " of making use of my Medicines or Druggs in his own private practice." Penalty if he mis-applied any drugs. He was to keep a Journal of Cases, and attend daily in " my Factory."

The Crowley MS. at Newcastle is, as has been stated already, really a minute book of the Court of Arbitration. The first entry, dated Dec. 31, 1806, opens with a record of a meeting, and of the arbitrators present, each man signed his own name, and internal evidence shows that they were all in the service of the firm.

They acted in an official capacity to hear applications from the workmen, and they had some power to decide issues. They were perhaps a committee, for there is frequently a note that this or that matter was to be referred to the " Court of Arbitrators," an over-riding authority possessing power to impose fines which must have fallen heavily on individuals convicted of infringement of the laws.

[43] *Ibid*, Order 99.
[44] *Ibid*, Order 113.

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Apparently the arbitrators met every week; but after 1815 the method of keeping the records was altered. There are longer gaps between the entries and far fewer details and the last thirty years do not furnish much pertinent information. At the end of the book, seven entries set forth agreements made between the smiths and their hammer men. The following is typical:—

> 1812, February 14, Articles of Agreement were made this day between Richard Ramshaw, William Bell and Thos. Evans. First it is agreed that the said Richard Ramshaw shall duly serve the said William Bell & Thos. Evans as a hammer man in the employment of Messrs. Crowley, Millington & Co., for the term of one whole year from the date hereof, and further until any debt that he may be in to the said Company at the Expiration of the Term aforesaid be fully discharged. Secondly, it is further agreed between the parties above-named that for every week's work duly performed by the said Richard Ramshaw the said William Bell and Thos. Evans shall pay or cause to be paid him the sum of 15s. 6d. per week; but in default of non-performance a proportionate abatement to be made."

From extracts made at Newcastle, the following throw some light on the way the founders' intentions were carried out nearly a century after the decease of the younger of the two. On December 31, 1806, an application received from William Summersides for a vice, concludes with a laconic note "Granted," but a similar request of William Rowels was rejected, although he was "to be employed to make nails, chains, for 2 months." A notice posted on October 8, 1806, ordered workmen leaving iron in their neighbour's shop longer than 24 hours to "leave a Tally with his name tied round his parcel (and if) in contempt of this order he shall leave his Iron without a Tally . . . he shall be mulcted any sum not exceeding Five Sh. at the Discretion of the Committee, one half for the Benefit of the Winlaton Poor, the other shall be given to the informer."

Many of the entries in this later MS. are of a personal character. From time to time, Benjamin Summerland "requests a loan of 5s.," and gets it every time, and if not singular in his need, he was more persistent than others whose applications were refused. Quite a number of these requests are for "a salary," and were put forward by girls—perhaps women. Mary Rippeth, quaintly described as "a real object," failed, but at the same court, Eley Heppel was awarded "4s. p. week." On March 25, 1807, the chainmakers applied for "an allowance for Chain for apprentices," which request met with a refusal, but at the same court "Jno. Biggin being unable to work for a maintenance being afflicted with rheumatic pains and other infirmities," was granted 1s. per week. A month later Anthy Smith presented a note—as the phrase went— asking for "Thos. Forster to strike to him," and as a favour his request was complied with on condition of his paying "Arrowsmith's debt."

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That some sort of method of payment by results was in vogue is apparent from various entries. At the court just mentioned, Summersides, to whom a reference has already been made, asked "to have his reckonings protracted on account of repairing his tools," that would hardly have been necessary had wages been paid by the hour or week.

Frequent applications for shops "in the Square" appear, and judging by such comments as "no shope vacant at present," those in possession were anxious to retain them. Similarly there are requests for "a stock," but indication of what a stock was, or of the privileges attaching to it, although those who attained to the position had to find a surety.

It was customary when fines were inflicted to recite the law under which it was authorised. Thus in September, 1808, before a full court of Eleven Arbitrators, James Hurst pleaded guilty to theft:—

> "We have had information against this person for selling 1 dozen tongs in Newcastle. . . . He has confessed the fact, acknowledged his having done wrong and promises not to repeat the Transgression. The Law 51 has been read, relative thereto, and each Arbitrator's opinion taken, when it appeared that 6 N were of opinion that the law ought to be mitigated . . . to a mulct of 2s. 6d.—5 N for 5s., and one that the law ought to take its full effect, he is therefore ordered to be mulcted 2s. 6d. by the majority."

The Committee, or Court, appears to have kept an old clothes store. When a vacancy occurred in 1807, "John Whitefield's note requesting to make the Poor's Cloaths" was too late to be considered, and William Rippeth, possibly a relative of the "real object," seems to have been appointed, for a year later he applied for payment for materials and work done for Edward Cowen, to wit:

> "Repair^g his shoes 1s. also a piece of cloth to make him a wistcoat breat, and an allowance of 6d. to pay for buttons and thread."

That was in March, and in May, Rippeth got half a crown for yarn with which to repair Cowen's stockings. In August, the tailor 17s. 2d. for more clothes for Cowen, of which total 9s. 8d. was for a pair of new shoes.

This firm seems to have kept on the cultivation of farm land, for an entry in 1813 records the fact that Thos. Biggin and Robert Parker jun. were caught trespassing in a field, and that they had taken "from thence sundry turnips." The culprits were fined 2s. 6d. each, and half the fines went to the poor and the other half to Jacob Bell who laid the information against them.

A pleasant interlude to the drab routine stands out in an entry to the effect that

> "Mr. Wm. Betts, late Schoolmaster and Clerk to the Poor having by his will ordered £5 to be given to the poor of Winlaton at the discretion of the Committee, we this day ordered that sum to be divided amongst twenty-seven poor people in such sums as their circumstances appeared to require."

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What happened after 1843 is obscure, but the Monthly Chronicle of North Country Lore and Legend, a Tyneside Miscellany, contains the information that in 1862 the then proprietors of the works "Cast into a furnace" a great many manuscripts relating to the business. If that were so, more's the pity!

Ambrose Crowley collected a nucleus of foreign workmen and founded his first works at Sunderland. Why did he choose foreigners in preference to Englishmen? Again, why should he, a Worcestershire man, have preferred Co. Durham to his native heath? It could not have been the question of coal supplies, for there were collieries in the Midlands which would have yielded all the fuel that his hundred men could have consumed. Moreover, his principal output was small wares, and John Leland had placed it on record in 1538 that in Birmingham "there be many smiths . . . that use to make knives and all manner of cutting tools . . . and a great many naylors," and the earlier Crowley MS. affords evidence that in two centuries not much change had taken place in the way work was done. Ambrose Crowley realised soon after he opened his warehouse at Greenwich, that if he were to add manufacturing to trading, his works would have to be in an iron and coal centre readily accessible from London. Dudley and Stourbridge were nearer than Sunderland on a mileage basis, but it was quicker to get by boat from the Thames to Tyneside.

It is only possible to guess the reasons for employing foreign and catholic workmen at the outset. Crowley came of Quaker stock and was a Protestant, and almost certainly he knew the Worcestershire workmen. He may have employed Belgian or French smiths at Greenwich before he made his big stride in the north. He may have had opportunities of comparing the mentality and skill of the two types. Teitjen, the Dutchman, was the supreme metal craftsman in London in William the Third's time, and a good many continental smiths were working in London. Crowley's advertisement in *The Postboy* may have been inserted with the express intention of attracting some of them.

Again, what led Ambrose Crowley to make the remarkable experiment that was carried to a successful issue on the Tyneside? The time was not ripe in Queen Anne's reign for anything recognisable as co-partnership in business, and Crowley's contemporaries probably regarded as madness his step in that direction. It was a tremendous risk that Crowley took when he made his radical departure from the old traditions, and instituted a comprehensive system of self-government in industry. The Law Book offers several complicated problems for solution by social economists, and is full of contradictions, but one thing is outstandingly plain; Ambrose and John Crowley, in their outlook on industry were a century in advance of their fellows. They never contemplated a reversal of their initial policy. When their intentions were not fulfilled they duly reprimanded the "slothful villans" whose negligence rendered void their good intentions, but they

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did not withdraw the authority they had deputed. Rather from time to time they extended the principle. When a council failed to compass the end, it was supplemented by a "comptrol committee" and when need arose for an extension of powers of discipline a court of arbitration was set up, competent to levy fines and inflict punishment such as would not be tolerated in a modern shop. The preambles to those laws which appertain to good government in Crowley's community are quaintly phrased, but they are marked by the spirit of strict justice, and a sense of moral responsibility. The type of mind represented by the Crowleys is not singular, it is possibly as old as the relations between master and man. What is remarkable is the complete justification of this early example of delegated authority of a communal character. When it is found that the principles laid down in 1700, perhaps even earlier, were working without friction, and with only minor modifications a hundred and ten years later, there can be nothing but admiration for the man who conceived the scheme, for the son who elaborated the details with such patient and painstaking thoroughness, and for a community that maintained the system with loyalty for so long a period. The one blot on the escutcheon is dependence placed on tale-bearing by the founders and their successors. The twentieth century need neither condemn nor condone the eighteenth in this matter. To lay information against one's fellow is no longer encouraged and hardly tolerated, but the Crowleys saw no harm in it, and Law No. 99 was expressly formulated to prevent the abuse of a practice which doubtless afforded the absent proprietors opportunities of checking malpractices, that might seriously have threatened not only their own interests, but the privileges they had seen fit to grant to their workpeople.

The Author did not read his paper in full but gave a resumé of its more interesting aspects. As an appendix[45] to his paper he submitted a précis of the Laws contained in the Winlaton Law Book.

Discussion.

Mr. G. F. Tyas observed that the Author had expressed regret that he had been unable to discover what finally happened to Crowley's works at Winlaton. Information was, however, available in a published work;[46] besides this he, the speaker, had been fortunate enough to obtain some particulars from a friend, Mr. A. Turner, a native of Winlaton, who takes an interest in the history of the district. From these sources he learnt that after the works had remained in the hands of Sir Ambrose Crowley, John Crowley, and Crowley, Millington & Co., for nearly one hundred and seventy years, the whole of the fixed plant, rolling mills, houses,

[45] Printed on page 95.

[46] Bourne, History of the Parish of Ryton, including Winlaton, 1896.

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&c., at Winlaton Mill, were in February, 1863, sold for the sum of £780. They were eventually taken over by Messrs. Raine.

Sir Ambrose removed his works from Sunderland to Winlaton Mill, afterwards extending them to Swalwell, Dunston and the Teams. He brought a number of workmen from Liége, then considered the best place for smiths in Europe; they taught the Englishmen to make nails for sheathing ships. In the palmy days of the factory, 1,500 men are said to have been employed. The smaller ware was made at Winlaton, and the larger, including the hoes for the plantations, harpoons for the Greenland whale fisheries, artillery for the Government, as well as the larger chains and anchors, were made at Swalwell and Winlaton Mill. The works comprised rolling mills, slitting mill, file-cutting and chain shops. The mills, forge hammers, and shears were kept in motion by nine water-wheels.

At the various works, a rigid system of registration was in use. On entering upon employment, a workman had to give his name, place of birth, place of abode, height, complexion, religion, &c., and these were carefully tabulated.

Every workman in Mr. Crowley's service had to sign an agreement as follows: "2nd May, 1720. Articles of Agreement between John Crowley, Esq., London, and the workmen engaged in his service at Winlaton, Winlaton Mill and other places in the County of Durham. I agree to give six months' notice before leaving my employment, and also agree not to work at any other place within forty miles of Newcastle. Penalty £50."

Many other strict rules were in force, *e.g.*, no publican could sue for debts contracted for drink. If any workman rebelled against the authority of the Court of Arbitration he was expelled and lost his employment.

The working hours of the establishment were from five in the morning till eight at night; and during the early years of the community little time seems to have been allowed for recreation and mental improvement; for the factory bell, which was a kind of curfew, rang every night at nine o'clock, when the workmen were expected to retire to rest. This, however, seems to have been disregarded at times, as an entry in the Ryton Church books, reads: "1745, Paid to the constable of Winlaton for giving notice to people not to keep late hours, 4d." The curfew custom was discontinued in 1860.

The social arrangements of this community deserve the highest commendation. When any workman was ill, he sent a note to the Court, and, after being considered by the Arbitrators, and found to be a deserving case for assistance, a sum of money was lent to him until he recovered. When disabled, or unable to work through old age, the workman received from the Court the sum of five shillings—and in some cases seven shillings—weekly.

The superannuated were known as "Crowley's Poor," and wore a badge with "Crowley's Poor," on the left shoulder. On the death of a workman, the

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widow either received a weekly allowance of two shillings and sixpence from the Court, or was taken into the employment at the factory to make nail bags. All workmen had to pay from 5d. to 8d. in the pound and were allowed the full benefits of the Court including medical attendance and schooling for their children. A surgeon was appointed to attend the whole of the workmen. These benefits came into force in January 1710.

Both Sir Ambrose Crowley and his successors looked well after the religious welfare of their workpeople. Winlaton Hall was at first licensed for religious sevices. Sir Ambrose also provided a gallery in Ryton Church for the accommodation of his workmen. A chapel was afterwards built at Winlaton, which had accommodation for three hundred persons.

Mr. A. Titley remarked that John Smeaton carried out work at Winlaton; one of the water wheels there was of his construction.

Mr. Rhys Jenkins said the paper was a first-rate one. The organisation described was unique, as far as he knew, in this country or abroad. It was true that Sir Humphrey Mackworth in his works in S. Wales had regulations as to moral conduct of workmen, but he did not institute welfare work or pensions.

It might be wondered why Crowley should have established works on the Tyne rather than in his native Worcestershire but it was readily explained by the cost of carriage. It would have been cheaper to bring goods from Liége to London, and it could be done without breaking bulk, than from Stourbridge to London. No doubt it was for similar reasons that the Hollow Sword Blade Co. put up their works on the Derwent close to. There was another reason why carriage would be cheaper, more certain and speedier, and that was the number of coal ships that were always going to and fro between Tyne and Thames.

The ironmongery turned out in England was not equal to that made for the Continent, *e.g.*, at Liége. In two instances, viz., frying pans and sheathing nails, the English workmen never attained the skill of the foreigner. The Privy Council proceedings revealed the curious fact that the workmen were catholic; he would have expected them to have been protestant—possibly there had been religious disturbances at Liége.

Where "stock" is mentioned, piece-work must be understood. The iron given out to the workmen was returned by him in the form of manufactured goods, less an allowed percentage of loss.

Captain E. C. Smith said that Sir William Bowes had been mentioned. No doubt he belonged to the old-established family of that name in the district.

Mr. D. Brownlie gave the parallel instance of the establishment of a line of vessels to London by the Carron Co. in the eighteenth century. He had been told that a free passage in these boats was offered to anyone who would undertake to work the carronades against the pirates who infested the coast.

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MR. E. W. HULME suggested that the peculiar organization described might have had its origin in the employment of foreign workmen; distinct evidence could be adduced of such workmen making their own terms of employment.

MR. YOUNG, in his reply, said he was pleased to have had Mr. Tyas's contribution and congratulated him on having cleared up satisfactorily what had been hitherto in doubt. He quite agreed with the remarks of Mr. Jenkins. He could not reply as to the Bowes family. Very few names of workmen were given in the Law Book, although there were more in the modern book, but he had not noticed names of foreign origin.

CORRESPONDENCE.

MR. J. MACFARLAN wrote that it was not unlikely that Bourne, the author alluded to by Mr. Tyas, had obtained his information from Dr. Aikin whose account[47] was based on "Notes taken at Swalwell, near Newcastle-on-Tyne, in September, 1793." The information thus became first-hand and therefore more valuable than if hearsay.

That part of the notes which deal with the technical conduct of the works is as follows:—

"Not less than a thousand men are employed in this manufactory: of this number, excepting those who are employed at the founderies, the forges, and the warehouses, each pursues his vocation at his own home, for here every separate article of manufacture is sufficient to afford exclusive employment to one, and often many men. By these means they acquire a celerity and adroitness far surpassing the dexterity of those whose attention is divided by multiplicity of objects; and as the workmen are paid by the piece, this power of execution is always preserved in activity. A boy, whom we saw, was fabricating a chain, made a link from a bar of iron, and added it to the rest, in less than a minute. . . . Here boys work for some time before they are bound to an apprenticeship. . . . In a period of forty years the numbers of the workmen had neither increased nor diminished except in a very few particulars. The number of manufactures too was not supposed to have altered, though the demands for the goods of the factory had increased . . . an equilibrium (that) might have been preserved by the increase of improvement of machinery, and the skill acquired by subdivision of labour. A tilt hammer, in particular, we are told had lately been erected at Winlaton Mills, of which the strokes were 520 in one minute. The machinery at this place, as well as at the forging hammers and slitting mills at Swalwell, are amply supplied with water by the river Derwent: nor are they but very rarely impeded by the tide which conducts to the doors of the factory the materials of their work. This navigation,

[47] The Athenæum: A Magazine conducted by J. Aikin, M.D., Vol. I., 1807, 564-8.

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however, extends not beyond Swalwell: where there is the foundry, the anchor manufactory, and others of a heavy kind, whilst the lighter articles are fabricated at Winlaton and Winlaton Mills. They have no furnaces here to separate the iron from the ore, and they cannot even forge sufficient from what is called pig iron to supply the artificers, but import very large quantities in bars from the Baltic. The very sand employed to form the moulds at the foundry is brought from no less a distance than Highgate.

From viewing the works we went to visit the warehouse where was quantity to astonish and variety to amuse and inform. Here we were shewn many instruments of which we before knew not the existence, and among the rest . . . the head of a hoe weighing four pounds, and intended for the use of the negroes in the sultry climate of the West Indies. And this, too, we were told was not the largest of its kind . . . Grindstones accompanied the implements exported to either Indies, for the tools were left unfinished in the edge that less injury might be apprehended from the accidents of packing and conveyance."

After describing the singular form of log-wood axes made (except the aperture for the handle) to resemble a wedge, the edge and back being equally tempered so that it could be used either as a mallet or wedge, the writer adds:— "Cannon does not form an article of their stores or manufacture except being employed as old metal, to be refluxed and converted into the more harmless implements of agriculture or culinary arts. Old anchors too we saw collected in great numbers; but these are more easily renewable into their old form (being entirely made by hand and hammer) than converted to any other purposes. The business of the anchor-smith seems to be one of the most important in the factory: we saw one of which the number was marked 8,241, and the weight 8cwt. 2qrs. 20hd., but learned some were manufactured to the weight of 70 or 80 cwt., which might be easily credited from the specimens that lay around us."

Mr. Macfarlan added that there was a still earlier account in print of the Winlaton works, and he would venture to cite it as well as a few others in the form of a bibliography:—

Jars, Gabriel. Voyages Métallurgiques, 1774. 4to, vol. I, p. 218.

Mackenzie, E. and Ross M. Historical, Topographical, and Descriptive View of the County Palatine of Durham, comprehending...Mines, Manufactures, etc. 1834. 4to, vol. 1, pp. 194-196.

Victoria County History of Durham. 1907. 4to, vol. 2, pp. 281-8. "Industries." (History of Crowley Works: with quotations from Law Books, etc.).

Ashton, Thomas Southcliffe. Iron and Steel in the Industrial Revolution. 1924. 8vo. (Numerous references to and vivid account of the organization).

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Appendix.

ORDERS AND INSTRUCTIONS FOR CARRYING ON THE WORKS AT WINLATON, 1692-1815.

PRECIS.

1.—Proof spy on the Mill clerks: prescribes method for keeping records of iron at Mills; Duties minutely stated, with forms; Proof to be made every week, and every six weeks, then sent to London.

2.—Orders new methods for dealing with accounts of ships' cargoes, also cartage between works and wharves at Newcastle; how to deal with cargo on arrival. The Cashier, on fraud, to pay penalty to informer.

3.—Prescribes exact form and method to be followed in respect of expenses at Newcastle. Previous rules have given "opportunity to some to be extravig't." Weekly accounts to be made out, and if extravagant, "Councell" not to pay them, but lay them before me (Crowley). Only one charge is allowed "without Councell Mint."

4.—Lays down new rules for payment of accounts, and to prevent cheating.

5.—Outlines Crowley's "Bills Currant," or Notes of Currency, with a counter-part. Long, elaborate safe-guards are outlined for working the system. An Accountant's investigation of this Order might yield valuable information on financing a big business in Queen Anne's day.

6.—Recites "clamourous complaints" as to quantity and quality of steel supplied to workmen. Wm. Wright is instructed how to keep stock, and charge deliveries against the men.

7.—Orders new way of collecting tool-makers' money, "to give them fitting encouragement." If a workman does not come for his money, or lets it lie in Cashier's hands, he shall lose it. Differences to be decided by "Comtee of Aggrievances," one for tool-makers, the other for workmen.

8.—Sets up a method of assessment for the poor; each active member of the community to contribute on the basis of his, or her, wages. No workman not guilty of breach of law to be assessed above a third part of his earnings: or a criminal (*i.e.*, a law breaker) above one half of his. Gives Sir A.C.'s payments. The Ironkeeper not to deliver any iron to persons that neglect or refuse to pay assessment.

9.—Gives instructions for slitting iron at the mills to best advantage; introduces standard Gauges for Cutters in "Slitting of Barr Iron into (nail?) Rods." Three pages of table of rods to be made from the bars.

10.—Forbids lending of money; but in cases of distress the "Councell" to assist. Forbids lending tools, material, etc., without being duly entered, as "severall fellonious Rogues" have removed goods under pretence of lending. Informer to have 10s. Workmen in need of bedding to be supplied up to 30s.

11.—Dated London, February 16, 169⁸/₉: a long instruction about drawing bills. To prevent servants and others robbing him, Sir A. Crowley has contrived "Currant Bills" subscribed by himself, and assignable, etc.

12.—Provides for maintenance of supply of coal "when I am not concerned with the renting of a colliery." Embodies a rule for measuring wains and carts against short measure. Postscript dated the Court day August 7, 1734.

13.—Prescribes method of delivering coal to the workmen: with checks to be used, and form of coal ticket.

14 to 17.—Deal with the "nailkeepers," and lay down rules for engaging them. Workmen's irregular methods lose much time: duties prescribed for Surveyor, Nailkeeper, Ironkeeper, Cashier, Warekeeper, Accomptant, in great detail. Taking on and instructing

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new workmen: they were to be sett to work at once. Frequenting ale houses and drinking in office hours forbidden.

Evidently the nailmakers worked by piece, but were required to provide a bond for honest service. Payment might be in kind—the organisation covered a provision store somewhere in the village as well as a village inn.

18.—Sets out Ironkeeper's duties: Deals with Tables shewing output of rods, etc.: kept in Binns: London to be kept advised of same. Sketches provisions against contents being removed. In that case, 5s. to informer.

At the time this law was issued it would appear that 3,462 bars of iron, weighing tons 89T. 11 cwt. 3 qr. 15 lb. were in stock.

19.—A bond to be given by any workman to whom is entrusted a stock of iron and tools. Gives form of bond then in use.

20.—Office of Cashier is a post "that lys open to sundry temptations." Particularises the conditions, rules, and moral and legal obligations ("to resist the Devil," etc.), he accepts with office.

21.—In 1686, "Designing Villains" have been trusted with cash which they perverted to their own ends. Sir A. Crowley, in great detail, orders that a weekly state of cash shall be prepared. It appears that this was the method of proving every person's cash which Crowley practised from 1686 at the Doublett, to prevent sham proofs.

22.—An order to the Clerk of the Mill: elaborates system for keeping track of production. (Dated October 17, 1702.)

23.—Entitled "Assessment for John Crowley, Esq." No date, but presumably after 1713. Designed to simplify office routine as to workmen's reckonings. No Cashier or Ironkeeper shall take any person's word for iron tools weighed but once. Hammermen who demand more wages than is due, liable to penalty to informer.

24.—Further instructions as to workmen's reckonings, and their payment. Latter to be kept private. Anyone that does not come to reckoning to be discharged.

25.—Collection of practical instructions for storekeeper on casking of goods, designed to remedy delays to Shipping and great hurries caused by "Disorderly Packing," e.g.:

Verse 5: Be sure to have very good casks and Dry to Pack all Bright ware in.

Verse 8: Never put two sorts of Nailes or Staples Loose Together in any one Cask.

26.—Confusion has arisen in London from "the ill-writing of Some Labells, (and) the Blotching of others." Explains in 13 verses what the Surveyor is to observe before despatching any ware.

27.—How nails are to be bagged,—38 different sorts are enumerated, and the schedule of abbreviations set out to indicate the contents. Some of the marks are arbitrary signs: others are contractions. Large bags the occasion of much confusion. Bags to be cut to suit sizes of nails, etc. Tallies to be in bags to denote contents, and special kinds of nails:

INTERPOLATION:—An addendum dated April 7, 1713, *re* Order 16, that relates to drinking between officers and men. Surveyors and other Officers frequented ale houses, and accepted treat from workmen whose bad work they screened "for a Pott of Beer"; and were abusive to good men who would not treat with them. Treating prohibited under penalty to informer of 2s. 6d., and 2s. 6d. to Winlaton Poor.

Another note relates to reckonings of anchor smiths, and men who made grapnells.

28.—Instructs Nailkeeper how to keep records of goods in stock, and in transit to London. At every shipping to make a Proof, but never to exceed two shippings. All wares designed for London to be sent to Blaydon. Sample Proof by Nailkeeper:—

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Nails in Richard Griffin's hands, pr. 3.

Parcell.	Cask.	Sorts.	Price.	lb.	oz.	ts.	8	Cr.
	8312.	24 doz. Tinned Latches ...	3/6	176	00	03	12	00
		12 doz. Crooked Spring Bolts .	2/6	188	00	06	17	06
		43 doz. Streight Do., 1 pair trace chaines, 6 lb. ...	35/6	5	12	00	01	10
		2 doz. ½-inch Augur Bitts ...	7/0	10	08	00	14	00
		32 lb. Filling War. 2. m. ...	8/0	64	00	00	06	00
	8312.	30 lb. Short Sheathing ...	0/3	25	00	00	06	13
				469	04	12	07	07

29.—Deals with Customs and Subsidies: Recites Subsidies granted by Charles II. and William and Mary regarding imported Iron; instructs officials how to deal with "keels" as they reach Newcastle.

30.—Orders the way iron is to be loaded and unloaded at Blaydon or Swalwell, and how weights are to be checked. Owing to "heedless counting," a Teller is appointed to hand bars out of ship's holds, etc.

This new routine implies that much roguery prevailed.

31.—Deals with claims arising out of shipping deliveries; with full instructions in special cases.

32.—How the Iron from Mills 1 and 2 are to be handled and accounted for. After the "carriage man" brings up iron from the Mill, Order instructs the Ironkeeper how to proceed to prevent error, or fraud. Accomptant fineable for neglect. No Iron or Steel to be delivered to any workmen belonging to Winlaton except upon Note by two of Comtee. Example:—

"To Mr. Arthur Hodge.

"You are desired to permit the bearer hereof, Richard Plashett, to see 3 ff. of Iron roll'd to his sizes fit for square Shovel Panns. But upon no pretence to be delivered till it comes to the Ironkeeper at Winlaton." Further strict orders about weighing Iron, etc.

33.—Deals with disorders caused by workmen "rummaging for iron." They must pay the damage. Defines duties of Ironkeeper every day there is a sale of iron to workmen; also his procedure where bundles of iron, or rod iron, are taken away by men.

34.—Further instructions to the Ironkeeper regarding reckonings of workmen. Crowds not to enter Iron warehouse; but only 2 or 3 at a time, and never more than 4.

35.—Forbids smoking of tobacco except in smiths' shops, or dwelling houses. "It has got up to much greater extravagance than ever." Mentions fire at Swalwell, May, 1715, believed to have been caused by fire from pipe of tobacco.

36.—Regulations to ensure maintenance of stocks of iron at Winlaton, and in the Mills: Every Monday morning at 6 o'clock Surveyor and Nailmaker at Winlaton to make estimate of Barr Iron required for week; and all stages of the work to be sent to me (Crowley) every Thursday.

37.—Procedure when a "claim" of Iron is landed at Swalwell or Blaydon, as to weighing, etc.; "Handy labourers" to count and weigh Barrs: sort them for binning, etc. To observe and report whether Barrs are what they seem to be. "Cracked" iron is to lie by for Anchors: the sound and true to be used for Boltstaves 12 feet long, etc. All Particulars to be sent to London to Crowley. Questions as to difference in size and quality to await his directions.

38.—Orders new ways to protect the "Odd Ware Trade." The Ironkeeper has unduly favoured some of the Nailmakers and allowed them to have "extra iron" instead of

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common quality: "great and grievous abuses in my Clerks and workmen," with regulations against them. Pieces for the Anchor, Smith, or Anvil makers, as Comtee of Survey shall direct: but no undue preference in Iron to be allowed.

39.—Instructions for bundling iron for stores (for working up) and also for despatch by ship to London. The weighing and bundling to be 3 kinds:—

Common Iron, 56 lb. each with 2 bands.

Extra Iron, 53 lb. each, with 3 bands

Clean Iron, 50 lb. each, with 3 bands.

Tallies to be on all bundles for London; and Clerk of Mill to test weighing bundles, etc.

40.—Order furnishing the Warden at the Mill with his authority, and laying down the way he is to perform his duties. They were to be "done without favour or affection, or hatred or ill-will." The duties amounted to a police, or barracks, supervision of coming and going, etc. "Any one absenting himself without notice, the Warden to draw a line thro' hour and minute of his last come"; and no one allowed out of the "square" till 5 in the morning in summer and day-light in winter mornings, except for the use of the service." Warden to keep a Time Book, "as I have been horribly cheated by the baseness of Sundry Clerks," which is to be sent to Swalwell at intervals. A person in the Common List to go round the boundaries twice every day, etc., etc. 51 verses in this Order, which are supplemented by

41.—Rules for keeping the Mill journal: it is to record all orders for cutting iron; verbal orders by Chief Officials; Faults of persons employed in the Mill; Marks of Iron cut or rowled, and what sizes, etc. "Actions of all that are diligent and support my interest, so that I may have them in my thoughts, to return a suitable reward."

42.—Regulates contracts between management and men and outsiders. Stringent conditions "to prevent charging me with more money than is really due. No person to make a Contract above the value of 2s. English, and no Councell to make one above £5. Examples given for guidance.

43.—Irregularities of some Ironkeepers have been discovered. Fresh rules ordered "to check carelessness or dishonesty of Ironkeepers." They are to be bound by numerous Conditions for honest fulfilment of duties (3 pp. folio).

44.—Mill No. 1, having so increased in size and importance, it is desirable to institute a Mill Committee to act under the Council at Swalwell; "to the Ease and Tranquility of my workmen." Members of Committee must sign Declaration before they may peruse my letters: must meet every morning at 9. No member to be absent without reasonable cause: to keep a Journal, and send all letters requiring my attention. States powers of Committee: voting, etc., secrecy: workmen not to be kept in pay when nothing to do; and if so kept for more than 8 days, Warden to pay them himself.

45.—"Unskilful, negligent and corrupt Surveyors . . . have not taken due care to prevent errors in making goods. "Surveyors to be properly qualified, or pay damages for their ignorance: must give workmen proper Patterns or Measures upon sticks: to direct them and not find fault where there is none, and prevent them running into mistakes. New workmen to receive abatements for want of skill, etc.

46.—Shipping. "I (Crowley) am an extraordinary sufferer by negligence and delays of those in care of shipping my goods to London." Instructions for stowage of Iron aboard ship and its despatch to London. Advice and Rules imposed (with forms) for every likely contingency in receiving and shipping cargoes (6 pp. folio).

47.—Instructions for paying keelmen who put cargo into hold. The men to have a drink allowance. But not two keels where one will do.

48.—Amends the regulations in Order 23 ("Assessment," etc.).

49.—Sets up a Court of Arbitration, and describes the summary manner of procedure.

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50.—Order, dated July 28, 1700, sets forth the way the Court of Arbitration is to be conducted.

51.—Order: Each man to have enough material to continue at work but no more, so that there shall be no inducement to borrow or lend. "It is severely forbidden to exchange Iron or Steel with Foreigners, to my "unspeakable prejudice." Disposing of any kind of Iron by way of Truck or otherwise involves a forfeit of double the value. Several deletions, and an amendment dated December 10, 1734.

52.—Prohibits the use of iron for nailmaking unless served out by the Ironkeeper.

53.—Regulations in 75 clauses for the good government of the community so that "nastiness, gameing and clubbing for drink in the square above the value of twopence in three hours' space" may be mitigated. Also mentions restrictions as to heating and welding Steel. Those employed in blacking, grinding, or glazing, with heat, any Axe, Adze, Hatchet, or Howe, or any other tool that is to be steeled after same is tempered, shall be fined. (Page 179.)

54.—Relates to the issue of tools, and decides whether master or men is to bear cost of repairs thereto. Contains interesting details as to use and care of Anvils and Bellows, particularly to prevent damage to latter.

55.—Order regulating the laying of information.

56.—Entitled "Credits in Tune," and contains rules for office routine.

57.—Letters from London have not been coming through as they ought to do. New instructions issued about days for posting and the "margent" of each letter.

58.—Order in three clauses designed to prevent embezzlement.

59.—Deals with the taking on of men and their supervision.

60.—Provides for the assistance of those who, by reason of "folly, weakness or extravagance" have had recourse to the pawn shop.

61.—Affords evidence that John Crowley owned houses in which the workmen dwelt, and that the firm assumed the responsibility for the rent of others leased from other owners of property.

62.—Instructions for running the Mills: prohibits the removal of coals and candles; how the stocks of iron are to be protected: hints as to steeling of axes and tools. A repeat of Order in No. 53 that Tools are not to be heated after being tempered, etc.

63.—Regulations for the care, repair, and maintenance of tools: who may and may not have them; how the records of issue are to be kept; penalties for infringing the rules.

64.—Steps to be taken to prevent the loss and dispersion of tools when a workman absents himself, or is discharged.

65.—Missing.

66.—The stock of Iron at the Mills is to be taken every Saturday, or at other intervals.—A "Posthouse" is mentioned in regard to goods.

67.—Provides for the checking of stock and its marking, in order to facilitate identification. Gives a short List of the different kinds of Iron, with their different Marks.

68.—Speaks "of such grounds as I farm in the Bishoprick of Durham," indicating that farming was a branch of the enterprise. A husbandman and a wainman were to be kept. A bull was also to be provided. Directions given as to Hay, Oats, grazing of Cattle, etc.

69.—References to the rent paid for rooms in Seby's Hall, and elsewhere. Rents from 2d. a week for the buttery to 10d. for the great Hall. Gives Rent Roll from 1772 to 1782.

70.—The Warekeeper's duties, and his power to give credit defined.

71.—Lays down laws for Dunning in polite terms, with three delightful examples.

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72.—Opens with a preamble upon the "intrigues of some clerks in discouraging bidders," and sets up rules for the sale by auction of "pawns." Appears to be a provision for the disposal of chattel upon which the pawn keeper had a lien (*vide* Order No. 60).

73 and 74.—Provides for the regular delivery of coals to the homes of the workpeople at a low rate, and also for the supply of coal for use in the square. "Coal hole to be kept locked."

75 to 79.—Missing. (Ten sheets of MS. blank.)

80.—"Some disaffected clerks and other Designing Villains have insinuated that some of my Orders are not necessary, and that it would be foolish to comply with them." Crowley insists that his Orders must be obeyed, and calls for information about those who evade them. This is additional evidence that tale-bearing was encouraged, and paid for in hard cash.

81.—The Treasurer at Winlaton is to assume the custody of the standard beams and weights.

82.—Order providing for three ledgers (spelt Leidger), namely, the Collectable Ledger, the Prime Stock Ledger, and the Specie Ledger, the respective purposes of which are explained.

83. As management is likely to fall into too few hands, and the business may suffer for want of "advise," a "Grand Councell" to be set up with a "comptrol Committee." Recommends Councell, etc., "to keep my people quiet and peaceable: shew them a good example, and shun Za Goodeson . . . the promoter of Villany, Vice," etc.

84.—Missing. (Seven sheets blank.)

85.—Extravagance is discouraged, and certain workmen or clerks are indicated for whoreing, pride, and high eating, gameing, and sotting and trading to the hurt of the business. The Treasurer is to pry into the matter and report to London. [Marked W. Letter Book, Fol. 3.]

86.—The outwork men are bringing into store badly made nails, "of Cold Short Iron that I allowed Tough for," due, it is alleged, to the quality of Swedish iron used, which is referred to as "uncertain." Regulations for discontinuance of buying iron outside.

87.—Two short notes for the better keeping of accounts at the Mills.

88.—Twenty clauses defining the duties of the Cashier in his relations with the clerks and workmen.

89.—Thievish and cheating people may be outlawed at the discretion of the Council. During the period of outlawry they are forbidden entrance to the warehouses, mills, and shop. If they repent, the outlawry may be lifted, but only by John Crowley, or the Council in London.

90 to 95.—Missing. (Ten sheets blank.)

96.—Described as old Law: against frauds by the Ironkeeper, who may lend his . . . or leave his warehouse door unlocked. The list of his "crimes" shews some curiously tricky ways of defrauding. Crowley stigmatises two "of the blackest villains" who had almost ruined the Works.

97.—A fund is to be formed for the care of the poor, and the education of the children. Defines the relative position of the Clerk and the Chaplain, and states the duties of each office.

98.—Missing.

99.—Informers are to be encouraged, and are promised protection, and instructed how to mark letters for London so that the letter goes straight to John Crowley.

100.—Protests that the charge for candles has been so extravagant that there is reason for believing that they have been used for purposes otherwise than "my service doth require." Rules are laid down for the sizes to be ordered. The wicks are to be of cotton, free from any mixture of Dutch or other yarn. Orders to the chandler are to

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specify "candles free from kitchen stuff and dripping, and of perfect clean tallow without mixture." Candles (bespoke) to be 10¼ inches long in tallow, 12 to a pound, and to have six threads in the Bow, or 12 in the wick. The other sort of same length: 8 in the lb., 10 threads in the Bow, or 20 in the wick. Warekeeper not to sell any of the Cotton wick candles.

101.—Accounts rendered to London have been made out in such great disorder as to constitute "a bad precident for young clerks to be led by." Winlaton in future to work to a form which is dated 1712.

102.—Missing.

103.—Monitor to be appointed. The details indicate that his duty was to ensure time-keeping.

104.—Explains the way records of stock are to be kept when it is served out to the workmen.

105.—States the duties and privileges of the Chaplain, and the fees to be paid in certain circumstances.

106.—Sir Ambrose Crowley is in the habit of making gratuities to encourage industry. Form of receipt is given which will protect the recipient against the suggestion afterwards that the money is a repayable loan.

107.—Describes an Old Law. Embodies a series of "formal specimens" which the Council are to follow in dealing with claims against the fund under its control for the benefit of the poor.

108 to 111.—Missing.

112.—Sundry Instructions to the Cashier.

113.—Doctor and Chirurgeon to be appointed.

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A Sketch of the Industrial History of the Coalbrookdale District.

By Rhys Jenkins.

(*Read at Shrewsbury School, June 19th, 1924.*)

To the Members of this Society, Coalbrookdale and its vicinity is a district of exceptional importance. It was at Coalbrookdale that the problem of smelting iron with pit coal, or rather with coke, was solved. On the tramway from Coalbrookdale to Horsehay, cast iron rails were first laid instead of the wooden rails previously used. The first bridge ever built of cast iron, or perhaps of iron in any form, is that which crosses the Severn at Ironbridge, and a little lower down the river was built the first iron boat. At Coalbrookdale were made the first cast iron cylinders for steam engines, and at Broseley one of the very first of Watt's engines was erected.

It is not proposed to deal here with the early history of ironmaking in Shropshire; it will be sufficient to say that the blast-furnace made its appearance in the county about the middle of the sixteenth century, say, fifty or sixty years after its first introduction into England. At the beginning of the eighteenth century there were perhaps half-a-dozen furnaces at work in the county; they were of small capacity, making on an average from 5 to 10 tons of iron per week, and they used charcoal as fuel. One of these furnaces was in Coalbrookdale, and in 1709 it was leased by Abraham Darby, who had previously been in business in Bristol. A few years later he put up a second furnace. I daresay some of you noticed during our visit to-day the date 1658 on a lintel of one of the old furnaces.

For generations the Darby family was intimately connected with Coalbrookdale; from 1709 to 1791 three Abraham Darbys in succession reigned over the works, but with intervals between them, for they were short-lived men and left sons under age.

That the smelting of iron with coke was first successfully accomplished at Coalbrookdale is unquestioned, but the published accounts do not agree as to whether it was done by the first or by the second Abraham Darby. In a manuscript account by the late Mr. W. G. Norris, who was the manager of the Coalbrookdale concerns from 1867 to 1897, had access to the records of the

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company, and was greatly interested in its history,[1] he gives the credit to the first Abraham Darby, and says that "it has been the united contemporary statement and unquestioned tradition that this," the successful working of the furnace with coke, "was entirely accomplished by him." This statement is supported by remarks which seem to be based on the Coalbrookdale records, but unfortunately the references and quotations are too meagre to be quite satisfactory. However, it does seem clear that the credit is to be assigned to Abraham Darby I., and that coke was in regular use before 1717, the year before his death. It is somewhat remarkable that the process had been in use for thirty years before the appearance of the first mention of it in print—that of Mason in the "Philosophical Transactions" for 1747. Mason visited the Dale in 1745, and we gather from his account that it was at the Dale furnaces only that coke was employed. It seems surprising that in the interval the neighbouring ironmasters had not taken up the new method. Perhaps the explanation lies in a remark of Mr. Norris's that the men employed at the forges to convert the pig into wrought iron objected to the coke pig iron and required to be paid at a higher rate for working it. This meant in practice that the forgemasters preferred to buy charcoal pig, and the coke pig was used only for foundry work, which at the period was not carried on, at any rate to any considerable extent, at any other works in Shropshire.

It is probable that the Horsehay furnace of 1754 was the first outside the Dale at which coke was used as fuel. This was followed in a few years by the Ketley furnaces, and both these works were branches of Coalbrookdale.

A list of furnaces in 1740, which assigns six to Shropshire, does not distinguish between charcoal and coke furnaces. Before the end of the century a vast change had taken place; the coke furnace was in use all over the country, and the total make of pig iron in 1788 was 61,300 tons, as compared with 17,350 tons in 1740, and of this 61,300 tons, 48,200 tons had been smelted by coke. Naturally this extension in the production of coke pig iron was at first most marked in the neighbourhood of Coalbrookdale, and that small area became for a time the largest iron producing district in the country. The list in 1788 shows that Shropshire had 21 coke furnaces, and produced 21,300 tons of coke pig iron, nearly one half the total quantity for England and Wales. The make per furnace, 1100 tons, exceeded that of any other district except Glamorganshire, which showed the same figure. At the same date there were still three charcoal furnaces in Shropshire with an average make of 600 tons per annum. Eighteen years later, in 1806, the number of coke furnaces in the county had doubled, and the make had gone up to 55,000 tons, but the increase for England and Wales had been still greater. Staffordshire had now the same number of furnaces, but showed a lower production per furnace. The

[1] This MS. appears to have been utilised in the preparation of the "Industries" section of "The Victoria History of Shropshire."

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Old Park and Ketley works were the largest producers of pig iron in England, but their product was exceeded by that of one of the Welsh works, Cyfarthfa.

A hundred years ago the make of pig iron in Shropshire was about 60,000 tons per annum, and the furnaces numbered 41. They were:—Broseley, 2; Barnetts Leasow, 2; Benthall, 1; Calcutts, 2; Coalbrookdale, 2; Dawley Castle, 2; Donnington Wood, 3; Horsehay, 3; Hadley, 2; Ketley, 3; Lightmoor, 3; Madeley Wood, 3; Old Park, 4; Snedshill, 2; Wombridge, 3; Wrockwardine, 2; Lawley, 1; Langley, 1.[2]

Enough has been said to afford an idea of the great importance of the substitution of coke for charcoal in the smelting of iron. Coalbrookdale was the scene also of an early attempt to use pit coal instead of charcoal in another branch of the iron manufacture, *i.e.*, in converting the pig into wrought iron. In 1766 the brothers George and Thomas Cranege, one of them a workman at the Dale, obtained a patent for "making pig iron or cast iron malleable in a reverberatory furnace with pit coal only." The first experiments were made in an air furnace at the foundry with promising results. A small furnace was then built for the purpose and was worked for some time, but difficulty was experienced through the burning-out of the furnace-bottom, and in keeping uniform the quality of the product, so the process was soon given up. This was some fifteen or sixteen years before the date of Cort's epoch-making puddling process.

We may now turn to another phase of the activities of Coalbrookdale, that of ironfounding, and the application of cast iron to new uses. Ironfounding had been carried on in England long before the time of the first Abraham Darby, but the field for iron castings had remained quite a limited one. It is sometimes stated that he invented cast iron pots. This is incorrect; what Darby did was to make a particular shape of iron pot—a bellied pot—in a particular mould—a sand mould. He succeeded in applying a method of moulding already in use for brass pots to the production of iron pots. Dr. Percy's[3] account of this event is very interesting, but as it is rather long and is pretty widely known, it will suffice here to give the main facts. Darby, who had set up in Bristol as a maker of malt mills, entered into a partnership with certain other persons to establish a brass foundry. He procured workmen from Holland, and the foundry seems to have begun its career prosperously. Darby then conceived the idea of making those bellied pots in the cheaper material iron, instead of in brass, and got the Dutch workmen to make the attempt. The attempt was not successful, but their operations had been watched by a lad, John Thomas, then at the works, who though he saw the reason for the failure. He approached Darby with his idea. Whatever it may have been it seems to have solved the difficulty, and between them Darby and Thomas succeeded in producing a bellied iron pot. Soon after this Darby withdrew from the brass

[2] The sites of these furnaces are shown on the map of the district, Plate XIV.
[3] Iron and Steel, p. 886.

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foundry partnership, and, bringing with him young Thomas, came up to Coalbrookdale, where, says Dr. Percy, "the method of moulding arrived at by Thomas for more than a hundred years was practised and kept secret with plugged keyholes and barred doors." This statement is one that we must take for what it is worth, but it does seem that this initial mastering of a technical difficulty indicates the spirit in which the Coalbrookdale foundry was conducted for many years, and that the craft of moulding and ironfounding made great advances there. In respect of ironfounding there can be little doubt that Coalbrookdale soon became one of the leading places, if not the most important place, in the country, and that men who had been trained there were much sought after. We know that when Dr. Roebuck started the Carron Foundry he induced one of the Dale staff, Robert Hawkins, and two or three moulders, to go with him. Another man trained at the Dale was Peter Price, a Cornishman, who founded the now forgotten Neath Abbey Ironworks in Glamorganshire.

The records of the Coalbrookdale firm show that from 1724 onwards they were casting cylinders and other parts of Newcomen engines to be erected in all parts of the country, and for some years they seem to have had a monopoly of this work, at any rate we have no evidence of cylinders being cast elsewhere until about 1760. The use of the engine in the district begins about the year 1740; several were put up about that date or soon after for pumping in mines, and for returning water to the water wheels used to work the bellows of the blast-furnaces.

Although the Coalbrookdale Company was the oldest and largest maker of cylinders for Newcomen engines, the cylinders for Boulton and Watt's engines were made by a rival ironmaster, John Wilkinson, at his works at Bersham, near Wrexham. As most engineers are aware, the preference was due to the superior boring machine used at Bersham. Wilkinson owned, among other works, the New Willey blast-furnaces on the Broseley side of the Severn, and to supply blast to these furnaces he put up one of Watt's engines. This was set to work in 1776, and it shares with an engine put up at Bloomfield Colliery, near Tipton, the distinction of being the first of Watt's engines erected outside the Soho Manufactory. The New Willey engine was followed by a number of others in this district, which later became the field of a great many experiments in engine construction. The only one that need be mentioned is that of Heslop; several of his engines were put up here and continued to work for a number of years; possibly some of them are still to be seen. It is related in connection with one of these engines, near Ironbridge, that it was tended by an old woman—a rare instance of a woman carrying on engine driving as a vocation.

To go back to earlier days and deal with the application of cast iron for the rails of tramways; just as with the introduction of coke for iron smelting, we have two stories. According to one this material was first used by Abraham Darby II.

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on the tramway between Horsehay and Coalbrookdale, say, between 1750 and 1763. According to the other, the credit is to be assigned to Richard Reynolds, who was the manager from 1763 to 1768. Mr. Norris's account does not mention the first story, but makes it clear that Reynolds was instrumental in laying down a considerable amount of iron rails between Ketley, Horsehay and the Dale; he says that in the years 1768-1771, inclusive, 800 tons of cast iron rails were laid. It is possible that a short experimental length of line had been laid by Darby, and this proving satisfactory, upon his death in 1763, it fell to Reynolds to carry out the idea on a large scale. Norris does say that Darby for the wagons used a cast iron wheel, with an inside flange, and a cast iron axle.

The application of cast iron that remains to be mentioned is that to bridge building. The bridge across the Severn at the place which has become known as Ironbridge was the first bridge, and indeed the first large structure of any kind, made of cast iron. It was erected in 1779, and is of 100ft. span; the land arches on the Broseley side were not parts of the original structure, they were added in 1800. The members of this bridge were cast at Coalbrookdale by Abraham Darby III., who was one of the most active promoters of the scheme for replacing the old ferry by a bridge. In this project Darby had the powerful assistance of John Wilkinson, another great advocate of the extended use of cast iron.

Wilkinson, as we have already seen, owned the New Willey furnaces in Broseley parish; from the furnaces he had laid a tramway to the river at a point a mile or so below Ironbridge. His wharf—Willey Wharf—was the place where he built the first iron boat in 1787. It was a barge intended for conveying the products of the Willey works down the Severn. The following years saw the construction of other barges at the same place.

So far we have been considering only the manufacture and applications of iron; certainly it is in this connection that the district stands out most boldly, but a good deal may be said about other industries.

At the Calcutts, on the southern side of the Severn, between 1780 and 1790, Lord Dundonald set up works for the distillation of pit coal. He coked the coal in large ovens and recovered the by-products. His process was taken up in other parts of the country, and it seems likely that the process of producing coke in ovens, as distinguished from coking in mounds in the open, proceeded from his invention. It should be stated, though, that the production of mineral pitch and tar had been carried on at Broseley by Martin Ele, at least a century before Lord Dundonald entered the field.

The clay industries are still of great importance in the district. The manufacture of tobacco pipes at Broseley seems to go back to Stuart times. In the last quarter of the eighteenth century porcelain works were set up at Caughley and

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Jackfield; they were not of long continuance, but the Coalport works, which goes back to 1800, seems to have been a continuation of these older establishments.

It would have been interesting to have traced out the canal system constructed to connect the various iron and coal works with the Severn at Coalport, but we must content ourselves with a reference to another "first" for the district. The plan of using inclined planes instead of locks on canals was the invention of William Reynolds, the eldest son of Richard Reynolds of Ketley, and a man of great technical and scientific ability; it was first applied in 1788 to deal with a drop of 73ft. at the Ketley end of the canal from Oakengates to the Severn.

This rapid survey has not exhausted all the matters of industrial interest that the district contains, but enough has been said, I trust, to whet your appetites and to induce some of you to go deeper. I feel sure there is more to be found out yet.

The paper is illustrated by views of Coalbrookdale of date 1758[4] and 1788[5] respectively, Plates XV and XVI, and by the map, Plate XIV.

As the object of the paper was to put Members and Visitors at the Summer Meeting in possession of the main facts about the district they were visiting, and as the hour at which the paper was read was late, discussion upon it was reserved.

[4] This "View of the upper Works at Coalbrook Dale, in the County of Salop," was "Designed and Published by G. Perry and T. Smith, 1758. T. Vivares, Sculp." Plate size 20¾in. by 14in. It is marked "No. I.," and the title of the companion view, "No. II.," is "The South West Prospect of Coalbrook Dale and the adjacent country." It is not known whether there were other views in this set.

[5] This "View of the Iron Bridge in Coalbrook Dale, Shropshire, Taken from the top of Lincoln Hill," is one of a set of six engravings (plate size 21¾in. by 16in.) by different artists from paintings by George Robertson, published Feb. 1, 1788. They possess some technical value, and we therefore give the titles of the remainder:—

A view of the Iron Bridge taken from the Madeley side of the River Severn near Coalbrook Dale, in the County of Salop.

A view of Lincoln Hill, with the Iron Bridge in the Distance, taken from the side of the River Severn.

A view of the Mouth of a Coal Pit near Broseley, in Shropshire.

The inside of a Smelting House at Broseley, Shropshire.

An Iron Work for casting of Cannon and a Boreing Mill, taken from the Madeley side of the River Severn, Shropshire.

There is a coloured aquatint of Coalbrookdale of later date known which "exhibits the middle steam engine in the Dale, with the surrounding scenery." This is from *Picturesque Scenery of Great Britain*, from drawings by Loutherbourg, 1805.

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Summer Meeting at Shrewsbury, 1924.

The district chosen for the year's meeting was Coalbrookdale—perhaps the richest in Europe in associations with the early history of ironmaking. Shrewsbury was selected at a convenient centre for the visit, and Members gathered there on Wednesday, June 18th, the headquarters being at the Lion Hotel.

First Day's Proceedings.

Thursday, June 19th.

This day's excursion was devoted to Coalbrookdale and the Iron Bridge. On the way thither the motor char-a-banc halted at Wombridge on the Shropshire Union Canal to inspect the inclined plane used instead of locks for raising barges from the lower to the higher level of the canal, an invention due to William Reynolds in 1788. This inclined plane is one of the few remaining, and was in use to within a few years ago. Barges or tubs about 20ft. long were hauled up the incline on cradles by wire ropes passing round a large wooden drum actuated by a beam engine of the Watt type. There was also a second drum to pull the cradle out of the high level canal over the crest of the incline. The details well repaid examination.

Proceeding on the journey, the sites of the blast furnaces of Lawley and Horsehay were passed. Identifications on this and the subsequent day were facilitated by a map of the district prepared by Mr. Titley, copies of which were distributed among the party. This map, revised and reduced in size, is shown in Plate XIV.

Coalbrookdale was entered at its upper end, and on arrival at the offices of the Company the party was met by the manager, Mr. Jones, who conducted it over the older part of the Works.

The shell of a blast furnace into the breast of which a lintel, with the initials "E.B." and the date "1658," and two other lintels marked "Abraham Darby 1777," had been built, attracted much attention. It is surmised that the initials are those of a member of the Botfield family, who had a furnace nearby, but who, so far as is known, had no connection with Coalbrookdale.

Whether a furnace had existed here before the coming of Abraham Darby, whether it had been rebuilt or merely altered, and what the inside dimensions of the furnace had been, it was impossible to say. Close by was a similar furnace, but of later date; the tuyere holes were occupied by windows, and it was occupied

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as a store room. The Society has been fortunate in obtaining, through the kindness of Mr. W. S. Malcolm, the managing director, photographs of these places (*see* Plates XVII to XIX). The pig beds of both furnaces are used as foundry floors for the well-known productions of the firm, and present a site where iron founding has been carried on for a longer period probably than any other place in the world. High level ground outside is known as Cokehearths, which may have been where the coal was coked. A water wheel, some 60ft. diameter, that formerly drove some of the machinery, was also to be seen rusting away (*see* Plate XX).

Enquiry was made for any remains of the tramway to Horsehay laid down in 1767, but there was not even a rail to be seen, although narrow gauge tramway of the plate rail type (*see* Fig. 8), with cast iron ties, extend throughout the works.

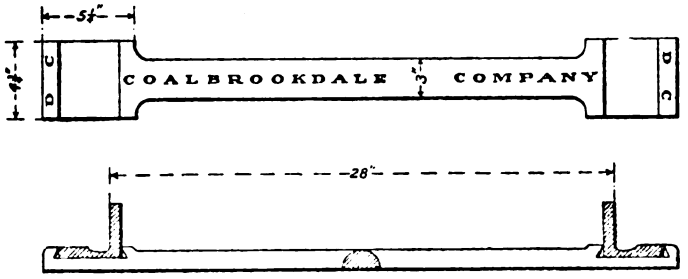

FIG. 8.

This rail is modified to a channel section where crossed by roads or other tracks, and the top surface has a projection cast on to prevent the wheels of trucks skidding when pushed diagonally across it. The engine shops of the Company, now leased in part to the Liverpool Refrigeration Co., were glanced at in passing.

The journey was resumed, and Iron Bridge was reached in time for lunch, which was served at the Tontine Hotel. Before rising from table, Mr. Dendy Marshall contributed the following notes[1] on Coalport porcelain and the works to which the afternoon's visit was to be devoted:

The Coalport Works were established by John Rose between 1780 and 1790. He had been apprenticed to Thomas Turner, of Caughley, and started on his own account at Jackfield about 1780, but removed in a few years to Coalport. On the death of Turner in 1799 he bought the Caughley works, and carried on the two until 1814, when he closed Caughley. In 1820 he purchased the works at Swansea and Nantgarw from Billingsley and Walker, who were retained in his service, and the three businesses were amalgamated. Billingsley, who was an exquisite flower painter, died in 1828.

In 1820, Rose received the gold medal of the Society of Arts for his "felspar porcelain," and the "Isis" medal, which was awarded for the best glaze free

[1] c.f. Jewitt, History of the Coalport, Porcelain Works, Art Journal, N.S., Vol. I., 1862, 65. a few excerpt copies of which were available.

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from lead, arsenic or other pernicious ingredients. The felspar came from Welshpool, the sand from Lynn in Norfolk, and the china clay from Cornwall.

Rose imitated Chelsea, Dresden and Sèvres china, including the marks. He died in 1841, and the works later became the property of William Pugh, but the style of the firm was always, and is still, John Rose and Co. Coalbrookdale is another name for the same manufactory.

Mr. Marshall also exhibited a copper token 1 3/16 ins. diameter (*see* Plate XX).

Obverse: View of bridge. Inscribed IRONBRIDGE AT COALBROOKDALE 1792, ERECTED ANNO 1779, SPAN 100 FEET.

Reverse: View of winding engine drawing up a boat. Inscribed INCLINED PLANE AT KETLEY 1789.

Rim: Engraved PAYABLE AT COALBROOKDALE AND KETLEY.

After lunch the famous iron bridge came in for a close examination, the interlocking construction and the method of erection both arousing much discussion. Great anxiety was expressed for the fate of the bridge when it was learnt that it has been proposed to pull it down and replace it by a modern structure in reinforced concrete.

Crossing over to the other bank of the Severn, the design of an old "10 o'clock" water-wheel, 50 ft. diameter by only 16¼ in. width of face, built up of cast iron with 20 wooden arms, was much admired.

The motorcar was not long in reaching Coalport, passing on the left the now derelict Coalport inclined plane from the Shropshire Union Canal to the Severn. At the works the whole process of porcelain manufacture—slip, throwing, firing in saggars, glazing, printing, gilding and burnishing were shown by guides. It was a surprise to see the potters' wheels still driven by apprentices by hand, but apparently it is believed that nothing else gives that delicate variation of speed that the potter needs. The other method of producing articles by casting was even more interesting. Into a plaster of Paris mould the china clay slip is poured. The mould absorbs moisture, the clay sets against the walls, and the remaining slip is poured out. In an hour or so the clay has contracted sufficiently to leave the mould easily. A point remarked on was that coal is used for firing, and that no pyrometer is employed, everything depending on the judgment of the furnaceman.

The party returned to the Tontine Hotel for tea, after which the journey to Shrewsbury was undertaken, the only stop being at Madeley Court, whilom the residence of Sir Basil Brooke, the Stuart Ironmaster, and subsequently the home of Abraham Darby I., of Coalbrookdale. The house, where not ruinous, and the lodge, are now let out in tenements to working-class families.

Arrived at the Lion Hotel, dinner was served, and a move was made to the Schools, where the party was welcomed in the Library by the Headmaster, Canon H. S. Sawyer, M.A., and the head of the Engineering side, Mr. H. G. Broadbent,

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B.A., Member. A pleasant feature was the presence of some of the Senior Boys preparing for engineering careers.

Canon Sawyer said that the tradition of the School had been one of devotion to the Muses, so that there was something almost incongruous in the idea of a body of engineers assembling there. The world was moving, however, and while still clinging to their traditions, he recalled that the School had produced a Darwin, and might yet produce a Faraday. Much had been made of the antithesis of the humanities and science, but his view was that one was the complement of the other. He had great pleasure in welcoming the Society.

Mr. Rhys Jenkins presented in abstract his paper on "The Industrial History of the Coalbrookdale District," which is given in full elsewhere.[2] Mr. Hall presented some notes, drawn up by himself and Mr. Titley, on the Shropshire Coal and Iron Fields. The Hon. Secretary, in the absence of the author, T. S. Ashton, M.A., of Manchester, gave a resumé of that gentleman's paper on "The Discoveries of the Darbys of Coalbrookdale." Time did not serve for any adequate discussion of these papers, and it was decided to leave them over till the beginning of the next session.

The School Librarian, Mr. J. B. Oldham, M.A., had prepared an exhibition of some of the School treasures, such as a Caxton, MSS., early water colour drawings by Samuel Butler, and book bindings, but time was all too short. The visit concluded by visit to Mr. Oldham's house, where coffee was served. The walk back across the river in the cool of the evening was delightful.

Second Day's Proceedings.

Friday, June 22nd.

This day was devoted to Uriconium, Much Wenlock, and Shrewsbury itself.

A visit was paid, first to Wroxeter—the site of the buried Roman city of Uriconium. The first excavations were carried out at the expense of Sir William Pulteney, under the superintendence of Thomas Telford. Later, work was done under the charge of the Shrewsbury Archaeological Society. The present excavations are being carried out through the liberality of Sir Charles Hyde, under the care of the Birmingham Archaeological Society. The Museum shed, where a large number of the objects found are preserved, was first visited, and here a short lecture on the history of the city was given by Mr. Atkinson, who was in charge of the excavations. The above-ground remains, and the ground plan excavated half a century ago, were inspected, and then the digging going on in a field some distance away was visited. An important mural inscription of the second century A.D. recently unearthed was seen. The Society had the pleasure of witnessing the dis-

[2] See page 102.

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covery of the bases of two columns forming part of an extensive colonnade, since completely exposed, one of the most important remains yet brought to light. Samian ware was also dug out while the party were on the site. It was with difficulty that the Members tore themselves away to resume the journey.

Much Wenlock being the next objective, there was no time to visit Buildwas Bridge or the ruins of the Priory, all that could be done was to view them in the distance. The route was along the Severn, through Ironbridge and Broseley; near the latter place the site of the New Willey Ironworks of John Wilkinson, also his house, were pointed out. (*See* Map Plate XIV.)

Mr. H. E. Forrest, the local antiquary, now kindly took charge of the party. A pleasant surprise awaited them at the luncheon at the Raven Hotel, the tables being decorated with flowers sent by Lady Catherine Milnes-Gaskell, who graciously invited the party to go over her house—the Abbots' Lodging of the old Priory—and further added to the privilege by personally showing its many interesting features. The ruins of the Priory, likewise the Guildhall with its old oak, the whipping post and the stocks were visited. The return journey to Shrewsbury was accomplished in time for tea, after which Mr. Forrest took the party, considerably diminished, rapidly over the Old School, where Charles Darwin was educated, now the Town Reading Room and Museum, pointing out the beauties of the half-timbered houses passed on the way. The Castle was visited, and its history, construction, and importance strategically, culminating in its dismantling after the Civil War, was reviewed. Before dispersing, the Members thanked Mr. Forrest very heartily for his kindness.

In Shrewsbury the Society heard with dismay that there is talk of destroying the beautiful Welsh Bridge, leading out of the City and replacing it by a modern bridge of greater width and span and less rise. It is earnestly to be hoped that vandalism of this kind may not be permitted.

Save for a few slight showers, the weather throughout was favourable. The welcome and courtesies that the Society received everywhere were of a very hearty and attentive description. Mr. J. W. Hall and Mr. A. Titley, who made the preliminary arrangements, are to be congratulated on having paved the way for what proved to be an enjoyable and interesting meeting.

We are indebted to the Editor of *The Engineer* for the loan of the block of the copper token on Plate XX.

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Notes and Communications.

Savery, Newcomen and the Early History of The Steam Engine.

By Rhys Jenkins.

PART II.[1]

THOMAS NEWCOMEN.

Materials for a biography of Thomas Newcomen are even more scanty than is the case with Savery; but we are in possession, at least, of the main facts concerning his birth and parentage, his marriage, and the date and place of his death.

The family of Newcomen is of Lincolnshire origin. It was first represented in Devonshire by the Reverend Elias Newcomen, who was presented to the living of Stoke Fleming in 1600. Elias was the younger son of Charles Newcomen, of Bourne, Lincolnshire (who came of the family of Newcomen of Saltfleetby in that county; he graduated B.A. at Cambridge in 1568-9, and afterwards conducted a grammar school in London; he married, in 1579, Prothesa Shobridge, of Shoreditch, and died and was buried at Stoke Fleming in 1614.

A grandson of the rector of Stoke Fleming, another Elias and a resident in Dartmouth, was the father of Thomas Newcomen, who was baptised on the 28th February, 1663, in St. Saviour's Church, Dartmouth.

Some of the members of the Devonshire branch of the family seem to have attained to positions of importance in the County. In 1651 Thomas Newcomen, of Dartmouth, merchant, probably the uncle of the inventor, executed a deed of indemnity in the sum of £3,000 in favour of William Lane, of Aveton Gifford, in the County of Devon, who had become his surety in a suit "then depending before the judges in the Upper Bench at Westminster." This would seem to be the same individual as the Thomas Newcomen, who died in 1653, leaving two sons, Robert and Elias, and four daughters, and whose Will mentions, among other items, "the house sold by my father-in-law Philpotte," and "Irish lands I adventured."

Thomas Newcomen, the inventor, is stated by Mr. T. Lidstone, of Dartmouth, to have been apprenticed to an ironmonger at Exeter. He then set up in business in his native town, and married, in 1705, Hannah Waymouth, the daughter of a

[1] This article is reprinted, with additions, from the Transactions of the Devonshire Association, 1914, by permission of the Council of the Association. Part I. appeared in Vol. III. of the Transactions of this Society, p. 96.

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farmer at Malborough, near Kingsbridge. He had two sons, Thomas and Elias. Lidstone says that Thomas was a sergemaker at Taunton, and that Elias assisted his father in connection with his engine work, and he mentions a third child, Hannah, who married Mr. Wolcott, uncle to the celebrated "Peter Pindar." Lidstone adds that Newcomen's portrait was painted in oils by "Peter," but is thought to be lost. According to the same authority, Newcomen, who was a Baptist, preached occasionally himself, and held meetings in his house, which led to his being prosecuted by the authorities.[2]

Mr. Lidstone was a diligent student of the history of Newcomen. It appears that in 1857 and again in 1873, he was advocating the erection of a monument to the memory of the inventor. A son and a daughter of Newcomen are mentioned by Dr. Richard Pococke, who visited Dartmouth in 1750. "Mr. Newcomen, an ironmonger here, with Captain Savery, invented the fire engine: his son and daughter found out the beautiful sea plants here on the rocks and on the shoar after storms."[3]

There are a very few contemporary references to Newcomen's connection with the steam engine. One of the earliest is afforded by an engraving, dated 1719, of an engine erected at Dudley Castle in 1712, when the inventor was forty-nine years of age. As will be seen later, it is likely that he had been considering the subject, perhaps experimenting, for twenty years before, but of this no documentary evidence is available. It is somewhat remarkable that no scrap of writing in Newcomen's hand, or anything bearing his signature, has been discovered.[4]

Newcomen died in London in 1729. There is an obituary note in the *Monthly Chronicle*, Vol. ii., p. 169: "About the same time (August 7th, 1729) died Mr. Thomas Newcomen, sole inventor of that surprising machine for raising water by fire."[5] Lidstone, from traditional information, stated that he died of a fever at the house of a friend in London, and was buried in Bunhill Fields.

The statement that he died in London is substantiated by, and the exact date of his decease is given in, a letter in Dr. Rippon's *Collections relating to the Bunhill Fields Burial Ground*.[6]

It would appear that a Thomas Newcomen, probably a son of Thomas Newcomen, the serge-maker of Taunton, and a grandson of the inventor, had come to

[2] *Newcomen*: Digest of a paper read at the Exeter Meeting of the Royal Archæological Institute, August 1st, 1873, by Mr. Thomas Lidstone, of Dartmouth. Reprint from the *Dartmouth Chronicle*.

[3] *The Travels of Dr. Richard Pococke*. Ed. by J. J. Cartwright (Camden Society).

[4] In the *Transactions*, Vol. II., pp. 115-117, there appeared a short paper on "A Holograph Letter of Newcomen," with a photographic reproduction of the letter on Plate XX. The letter is now in the Staatsbibliothek at Berlin; it purports to be written and signed by Thomas Newcomen, and is dated Dartmouth, May 7, 1725. It is a most interesting find, but in the present state of our knowledge, it is not safe to assert that it was written and signed by Newcomen in person.

[5] *Notes and Queries*, 6, S. Vol. III., p. 368.

[6] British Museum. Add. MSS., No. 28,513.

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London in 1794, and had applied to Dr. Rippon (who was a Devonian) for information as to the place of burial of his grandfather, and at Dr. Rippon's request had sent him the only particulars in his possession as to the date and circumstances of the death. The letter is on a single sheet of letter paper, and is addressed on the back to Rev. Mr. Rippon, Grange Walk, South Wark. It runs as follows:—

London, 5th August, 1729.

Dear Coz,

I am sorry that I should be the messenger of the ill tho, expected news of my Uncle's, yr Father's Death, for this morning about 6 of the clock it pleas'd the Almighty to take him out of this miserable world, doubtless to enjoy a far better. Indeed Mr. Wallin very prudently ordered the greatest care to be taken of him that possibly could. He had the advice of two Skilful Physitians every day. He had a careful Nurse continually with him, and one or two sat up with him every night. He was very submissive and patient all his Illness, and departed without a sigh or a groan, as if He had been fallen asleep. If you have any business here, which I can by any possible means do for you, I desire you would send word of it to

Sr Yr Sincere Friend & Servt,

JOHN NEWCOMEN.

Please to direct to me at

Mr. Thos. Dugdale's, Attorney at law,
in Token House Yard, London.

To Mr. Thomas Newcomen,
In Taunton,
Somerset.

London, Somerset Coffee in Ye Strand.
Octr. 4, 1794.

Revd. Sir,

Above is a Coppy of the letter you requested: shd anything come to hand in yr search, that wd assist me in my enquiries, please to direct for me whence this is dated, and you will much oblige.

Sr Yr Obed. hble. Servt.,

THOS. NEWCOMEN.

The statement, made by Lidstone, that Newcomen was buried in Bunhill Fields has been verified by reference to the Register Book of Burials, in which, under the date August 8th, 1729, is an entry "Mr. Newcomen from St. Mary Magdalen buried in a valt 00-14-00." The entry supplies incidentally the name of the London parish in which the death took place.

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From the terms of John Newcomen's letter it would seem not unlikely that Newcomen died in the house of Mr. Wallin referred to, and the latter may have been the same person as the Edward Wallin of London, Gentleman, who figures in 1725 as one of the Committee of the Proprietors of the Invention for raising water by fire.

It is clear that at the time of his death, Newcomen did not live in London, and, although his business engagements in various parts of the country would suggest the desirability of some place of residence less inaccessible than Dartmouth must have been in his days, it would seem that his native place, and perhaps the house in which he was born, was still his home. The house, in Lower Street, Dartmouth, in which it was said that he lived was sold and taken down in 1884 by the order of the Local Board of Health. Mr. Lidstone " purchased the ancient carved and moulded woodwork of its street frontage, &c., which he rebuilt in Ridge-hill in the parish of Townstall in Dartmouth, carefully replacing in the sitting room the clavel (wooden lintel) of the fire-place at which Newcomen (according to popular tradition) sat, when he first noticed the effect steam produced on the lid of his tea-kettle. The house is named ' Newcomin Cottage.' "[7]

Newcomen died intestate, and letters of administration were granted to his widow. On this point there is, in the Woodcroft Collection in the Patent Office Library, a note, dated Dartmouth, 23rd December, 1871, addressed to Bennet Woodcroft, in which Lidstone states: " I had an old gentleman staying with me this year who has told me a host of things about Newcomen. This gentleman's father wound up Mrs. Newcomen's (the widow's) business in Dartmouth." If we are to read this note as implying that Newcomen continued to carry on the business of ironmonger in Dartmouth throughout his life we are driven to the conclusion that he, in common with many another great inventor, had not found his invention pave the way to wealth.

The Newcomen Engine.

The Newcomen engine had very little in common with Savery's fire engine. It certainly raised water by the " force of fire," and it relied for its action upon the condensation of steam, but apart from this it was an entirely different machine. Savery utilized the condensation for the suction action of his apparatus, but he relied upon pressure of steam for the forcing action, and the pressure was necessarily commensurate with the height through which it was required to force the water. In the Newcomen engine steam at, or very little above, atmospheric pressure was employed, and the pressure of the atmosphere was relied upon

[7] " *Some account of the residence of the Inventor of the Steam Engine.*" By Thomas Lidstone, of Dartmouth, 1869. c.f. also page 134.

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entirely to perform the work; for this reason the engine was sometimes called the "atmospheric engine." An open-topped cylinder fitted with a piston was placed directly above the boiler, and above the cylinder was mounted a beam or lever pivoted centrally and coupled at one end to the piston and at the other to the pump rods. Steam was admitted beneath the piston in the cylinder and condensed by the injection of cold water, with the result that a vacuum was formed, the piston was thereupon pressed down by the weight of the column of air upon its upper surface and its downward movement produced an upward movement of the pump rods at the other end of the beam. The movement of the piston in the opposite direction was effected by the weight of the pump rods.

We are in complete ignorance as to the manner in which Newcomen first took up the subject, for we may dismiss as a fairy tale, the tea-kettle story. It has been said that he was employed in the erection of some of the early Savery engines; and again that the description and drawing thereof came into his hands, and that he made a model himself and so found out its imperfections. Switzer, who was personally acquainted with both Newcomen and Savery, states in his *Hydrostaticks and Hydraulicks*, 1729, that:—

> "I am well inform'd that Mr. Newcomen was as early in his invention as Mr. Savery was in his, only the latter, being nearer the Court, had obtained his patent before the other knew it, on which account Mr. Newcomen was glad to come in as a partner to it."

Again Dr. Robison in his article on the *Steam Engine* in the 1797 edition of *The Encyclopædia Britannica* has the following account:—

> "Newcomen was a person of some reading, and was in particular acquainted with the person, writings, and projects of his countryman, Dr. Hooke. There are to be found among Hooke's papers, in the possession of the Royal Society, some notes of observations, for the use of Newcomen, his countryman, on Papin's boasted method of transmitting to a great distance the action of a mill by means of pipes. Papin's project was to employ the mill to work two air-pumps of great diameter. . . . It would appear from these notes that Dr. Hooke had dissuaded Mr. Newcomen from erecting a machine on this principle, of which he had exposed the fallacy in several discourses before the Royal Society. One passage is remarkable. 'Could he (meaning Papin) make a speedy vacuum under your second piston, your work is done.'
>
> It is highly probable that in the course of this speculation, it occurred to Mr. Newcomen that the Vacuum he so much wanted might be produced by steam, and that this gave rise to his new principle and construction of the steam engine. The specific desideratum was in Newcomen's mind, and therefore when Savery's engine appeared, and became known in his neighbourhood many years after, he would readily catch at the help which it promised."

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The papers referred to have been lost sight of, and subsequent writers have had to rely upon Dr. Robison's note; there is, however, no reason to doubt its accuracy. This information establishes the fact that Newcomen was engaged in the problem before the end of 1702—Hooke died in March, 1703—and it suggests that he may have been so engaged before 1690, the year in which Papin published on the continent his plan for the production of a vacuum by the condensation of steam. The note clearly is subsequent in date to 1687, when Papin proposed to transmit power by means of a vacuum.

Galloway (*The Steam Engine and its Inventors*, 1881) suggests that although Newcomen may have been contemplating the construction of an atmospheric engine before the date (1698) of Savery's patent, he may have thought Savery's plan, when he became aware of it, to be superior to his own, and so deferred proceeding further with his scheme until it became clear that Savery's plan was a failure.

The persistence of the idea that a patent was granted to Newcomen in 1705 also seems to lend colour to the view that he was in the field almost, if not quite, as early as Savery. It has been established that no patent was granted to Newcomen; a search at the Public Record Office has failed to reveal even a petition for a patent in his name, and it is now the generally accepted view that Newcomen's invention was worked under Savery's patent. Probably it was held at the time that the grant to Savery covered all means for raising water by the aid of fire.

However, we do not learn of any attempt to apply the Newcomen engine in practice until the year 1711, or of an actual application until 1712. Desaguliers (*Experimental Philosophy*, 1744) states that Tho. Newcomen, Ironmonger, and John Cawley, or Calley, glazier, of Dartmouth.—Anabaptists—in the latter part of the year 1711 made proposals to draw the water at Griff in Warwickshire, but, their invention being rejected, they in the following March, through the acquaintance of Mr. Potter of Bromsgrove in Worcestershire, bargained to draw water for Mr. Back of Wolverhampton, where, after a great many laborious attempts, they did make the engine work.

This is the first cylinder and piston steam engine of which we have any record, and fortunately the contemporary engraving, already alluded to as still in existence, shows the construction fairly clearly. The print bears the inscription *The Steam Engine near Dudley Castle. Invented by Capt. Savery & Mr. Newcomen. Erected by ye latter* 1712. *Delin: & Sculp: by T. Barney*, 1719. The engine is shown with a self-acting valve gear, and with an arrangement for injecting water into the cylinder; but it will be observed that the print is seven years later in date than the engine. Whether the engine when first set up was so equipped is a moot point.

However, both these features, the self-acting valve gear, and injection into the cylinder, are shown in a print of earlier date, 1717, which has recently (1925)

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come to light and is reproduced to accompany the present reprint of this paper.[8] This engraving is of particular importance in that it is the earliest drawing, indeed the earliest document of any kind at present known, indicating the construction of the Newcomen engine. It will be seen that it is inscribed "H. Beighton, delin, 1717." Henry Beighton was born in 1686 at Griff, near Nuneaton; there he lived the greater part of his life, and there he died in 1743. He was concerned to some extent in the business affairs of the Newdigate family, apparently as a friend and not as a servant. It is likely that he knew Newcomen personally; in 1717, or perhaps earlier, he made the acquaintance of Dr. Desaguliers and it is pretty clear that it was he who supplied the drawings and description of the Newcomen engine which appear in that author's *Experimental Philosophy*, 1744. Beighton was elected a Fellow of the Royal Society in 1720.

Savery's patent and Act of Parliament, under which Newcomen's invention was worked, became vested in a company: "The Proprietors of the Invention for Raising Water by Fire," it is not clear at what date, possibly on the death of Savery in 1715.

In 1716 we find in the *London Gazette*, Aug. 11-14, an announcement by the Company:—

> "Whereas the invention of raising water by the impellant force of fire, authorised by Parliament, is lately brought to the greatest perfection, and all sorts of mines, &c., may be thereby drained, and water raised to any height with more ease and less change than by the other methods hitherto used, as is sufficiently demonstrated by diverse engines of this invention now at work in the several counties of Stafford, Warwick, Cornwall and Flint.
>
> These are therefore to give notice that if any person shall be desirous to treat with the Proprietors for such engines, attendance will be given for that purpose every Wednesday, at Sword-Blade Coffee-House in Birchin Lane, London from 3 to 5 of the clock; and if any letters be directed thither to be left for Mr. Elliot, the parties shall receive all fitting satisfaction and dispatch."

This important announcement, to which attention was drawn for the first time in *The Engineer*, April 7, 1882, p. 253, affords distinct evidence of the increasing use of the invention, but it does not support the idea that the steam engine had been introduced into the North of England as early as 1714, for it is clear that had the "Proprietors" known that there was an engine at work in Durham, or Northumberland, that fact would have been stated.

The Staffordshire engine was no doubt that "near Dudley Castle." The town of Dudley is in the county of Worcester, but it lies very near the Staffordshire border, and the print of the Dudley Castle engine is dedicated to the "Knights,

[8] This print was discovered in the Library of Worcester College, Oxford, by Mr. L. de H. Johnson, to whom our thanks are due for drawing attention to it. *See* also p. 132.

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citizens, and burgesses of the County of Stafford." This attribution is not inconsistent with the statement of Desaguliers, that the inventors in March, 1712, bargained to draw water for Mr. Back of Wolverhampton. Hitherto the point has remained somewhat doubtful in consequence of a passage in Shaw's *Staffordshire* purporting to be derived from the notes of Dr. Wilkes, that Newcomen "fixed the first (engine) that ever raised any quantity of water at Wolverhampton, on the left hand of the road leading from Walsall to the town, over against the half-mile stone."[9] Dr. Wilkes (born 1690, died 1760) after having been curate of Stowe by Chartley, set up as a physician at Wolverhampton in 1720, and any statement coming from him is entitled to careful consideration. His notes were written probably in the first half of the eighteenth century; they are now preserved at the William Salt Library, Stafford. Mr. John W. Bradley, the late librarian of that Institution, who checked Shaw's quotation against the manuscript notes, informed the writer that Wilkes makes no mention of Newcomen or his engine. It follows then that the responsibility for the passage rests with Shaw himself, and as he wrote a good many years after the event and seems not to have been a very careful writer, it ceases to have any particular value in this connection, although it is not unlikely that an engine did exist at an early date upon the site he mentions.

In the parish register of Bilston, Staffordshire, there is an entry under date April 8th, 1725, recording the baptism of "Thomas, ye son of John Hilditch, manager of ye Fire Engine at Tipton. He says that his settlement is in Bartolmey parish, Cheshire."[10] Tipton and Dudley are about a mile apart and it is probable that the engine was the Dudley Castle Engine.

The first engine in Cornwall seems to have been erected at a tin mine, Huel Vor, Wheal Vor, or the Great Work, in the parish of Breage which lies between Helston and Marazion. The accounts are not very clear, and it is possible that this was one of Savery's engines. However, Davies Gilbert, writing in 1838 of the same mine, refers to it as employing several steam engines of the largest size, and he adds that this mine "is said to have used, about a century ago, the first steam engine ever seen in Cornwall"; and again, "The steam engine, which consists essentially in a piston alternately sliding through a cylindrical vessel, invented by Mr. Newcomen of Dartmouth, had been used at least in one mine called the Great Work, in Breage, when Mr. Lemon came forward . . . commenced working a mine on a farm called Trowel, in the parish of Ludgvan, the property of Lord Godolphin, and named Whele Fortune, where the second steam engine was used."[11]

[9] Shaw: *The History and Antiquities of Staffordshire*, 1798-1801, Vol. II., p. 120.
[10] Mr. R. B. Prosser in *The Engineer*, Nov. 11, 1898, p. 468.
[11] *The Parochial History of Cornwall*, edited by Davies Gilbert, Vol. I., p. 127, and Vol. II., p. 83.

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As to the engine in Flintshire, it seems likely that it was at Hawarden. It is true that the historian of Hawarden places the introduction of the steam engine into that parish over twenty years later: " In 1738, a female, now known only by name, as Madam Haytrel, from the neighbourhood of Newcastle, in Staffordshire, engaged a coalwork at the Boar's Head in this parish, and erected the first fire engine ";[12] but in this it is clear that he is wrong, as it appears from the account books of the Coalbrookdale Ironworks that in October, 1724, a set of castings for an engine were sent to " Harding beyond Chester " to the order of Richard Beech of Walton, near Stone, in Staffordshire.[13] It is possible that this set of castings was for the purpose of replacing an engine with a brass cylinder erected prior to the date of the advertisement.

From the same account books we learn that as early as 1718, certain castings were charged to Stanier Parrot of Coventry for " ye fire engine." In August, 1725, the same persons obtained a set of castings for an engine, and in October of the same year Sir Richard Newdigate of Griff is charged with a set.

This brings us to the consideration of the site and ownership of the engine in Warwickshire, referred to in the advertisement of 1716. The statement of Desaguliers, that Newcomen and Cawley made an unsuccessful attempt to arrange for the erection of an engine at Griff in 1711, is very probably well founded, but it is not at all clear what interval elapsed before an engine was set up, or that Sir Richard Newdigate was the first to employ the new power in the Warwickshire coalfield.

In a map of the county of Warwick, made from a careful survey by Henry Beighton and dated 1725, are shown, extending along the outcrop of the Warwickshire coalfield from near Coventry northwards beyond Nuneaton, a large number of coalpits at three of which are indications " fire engine." These pits are at Hawkesbury, Fackley, and Griff, and are represented three and a quarter, four, and six and a half miles respectively from Coventry. Along the border of the map are given the coats of arms of residents in the county and among them is that of " Stonier Parrott of Fackley, gent." It is fair to assume that Stonier Parrott owned the pit at Fackley, and the writer is inclined to think that he owned the

[12] [R. Willett]. *A Memoir of Hawarden Parish*, 1822, p. 100. As to Madam Haytrel, the author states that the coalwork must have been given up soon after the year 1746, " it being certain that after that date, Madam Haytrel must have been considered as a very odious character in the parish; for having witnessed Sir John Glynne, Bart., and Rector Williams, upon their knees, on the Bowling Green, and overheard them drinking the health of the Pretender, she reported the transaction in London, and a King's Messenger was speedily dispatched to apprehend the offending parties.

[13] Quoted by Mr. W. G. Norris, of Coalbrookdale, in an appendix to Mr. Henry Davey's paper on the Newcomen Engine.—*Proceedings of the Institution of Mechanical Engineers*, 1903.

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Hawkesbury pit also.[14] We have seen that Parrott in 1718 was purchasing engine castings, possibly renewals for an existing engine with a brass cylinder, whereas the earliest definite reference we have to an engine at Griff is in 1723 (see below), facts which suggest that Parrott was the first in the field. On the other hand, as has been stated above, Desaguliers has in his book a set of drawings of an engine including a general view that is a very close copy (except in respect of the valve gear) of the Beighton engraving of 1717; now Desaguliers distinctly states that his drawings represent one of the engines at Griff, so it is quite possible that the engraving of 1717 was based on that engine, which must accordingly have been put up before that date.

By the courtesy of Sir Francis A. Newdigate-Newdegate, the writer has had the opportunity of inspecting the books and documents preserved in the muniment room at Arbury, Nuneaton. Unfortunately there is no trace of the proposal of 1711 referred to by Desaguliers, nor is there any mention of Newcomen, Cawley, or Savery. There are some books dealing with the Griff coal-pit accounts, but the volume for the period 1702-22, that which would have been most valuable to us, is missing. The volume for the years 1722-27, however, contains much of interest. If, as seems likely, there was already an engine at Griff in 1717, it is curious that the first entry under the heading, "Fire engine rent," is so late as 1723, 3rd July. The entry reads: "To Mr. Mears and at note £100. o. o." Mr. Meres was one of the Committee of the Proprietors of the Invention for Raising Water by Fire. Coupled with this entry is another, "Paid Mr. Mears's Bill for drawing up ye writings, etc., £5 10s. 0d." "The writings" would be the agreement to pay royalty or "rent" for the liberty of using the invention. There is no trace of a duplicate of this agreement at Arbury. It appears that at first Sir Richard Newdigate paid £150 a year royalty for a single engine; for the year 1725 and onwards to 1729, however, £300 was paid for two engines, and we may infer that the second engine had been at work for the greater part of the year 1725, and consequently that the castings supplied from Coalbrookdale in October of that year must have been for renewals. Possibly the first engine had a brass cylinder and the new cylinder was intended to replace it. There is in 1729 an entry of the sale of a brass cylinder.

Sir Richard Newdigate died in July, 1727, leaving a son Edward, a minor, and thenceforward, although a new boiler was put in for the engines in September, 1728, the coal mining venture seems to have languished. The balance sheet for

[14] Forty years or so later a "Mr. Parrott," possibly a son of Stonier Parrott, had coal pits and a fire engine at Bedworth, about half a mile further from Coventry than the Fackley engine shown in Beighton's map. This Mr. Parrott is probably identical with Richard Parrott, Esq., of Bedworth, who in 1769 obtained a cylinder and other castings for an engine from the Coalbrookdale Company.

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the period 22 July, 1727, to 28 September, 1728, shows "Lost by the Coal Works in the said period, £290 os. 8d."

An undated paper which appears to belong to the year 1728 states: "It is proposed to pay Lady Newdigate 200*li* per year until the time of Sir Edward's coming of age. And not to work or to cut any of the coal mine during that time save for the family use at Arbury. . . . It is considered that very little profit can be made at Griff while Hawkesbury is at work." Among other reasons brought forward for stopping the work is "The fire engine Act will then be expired and Griff engine which now pays 300*li* p. an. rent will then be rent free. In which article there will be saved to the family £1,500 os. od."

In another paper dated 4th Feb., 1730, on "The present state of the Coal Works at Griff. Taken by Rev. Mr. Ebdel, Mr. John Bousfield and Hen. Beighton," reference is made to two fire engines and to horse gins.

Another paper, discussing the policy to be adopted in connection with the coal pits, refers to the pits at Hawkesbury and Bedworth, both nearer than Griff to Coventry, the main place of sale: "The coal work at Hawkesbury near Coventry being in good working condition . . . and that coal work at Bedworth being now just getting in working and selling order and being a very thick vein." Further on it is pointed out the "the veins of coal at Griff upon which the Engines are placed are so entirely wrought out that there can scarcely be found coals to supply the engines," and it is suggested that new pits be sunk and the engines shifted. This paper is endorsed "1733 or 34, Heny. Beighton—opinion upon Griffe Colliery," but it is clear that the date is not correct, since the dismantling of the engines was begun in 1731, and in 1734 there is an entry "spent selling the last fire engine £0 5s. od."

It does not appear that the Newdigate family resumed coal mining at Griff until a number of years had passed. Towards the end of 1770, however, we find "An estimate of the expense of building a double engine and sinking a double engine pit for a new Foundation 106 yds. deep at Griff Colliery" and in 1773, and again in 1776, Sir Roger Newdigate purchased a large cylinder, and other parts for an engine and pumps, from the Carron Company.

To go back a few years, very soon after the appearance of the advertisement of 1716 an engine was set up at Austhorpe near Leeds. According to Smeaton, this engine had a cylinder 23 inches diameter and was erected by Calley.[15]

[15] Farey: Steam Engine, p. 155. We have very little information about Calley. Desaguliers couples his name with that of Newcomen in reference to the proposal in 1711 to draw water at Griff, and Farey, quoting Smeaton, states that he died at Austhorpe in 1717. This statement seems to be incorrect; from the Newcomen letter of May 7th, 1725, referred to above, it appears that Mr. John Calley, obviously Newcomen's partner, had died recently in Holland. It has been discovered that the death of a John Kelly is recorded as having taken place at the Hague on March 9th, 1725, and there can be little doubt that this John Kelly is identical with our John Calley. (Trans., Vol. II., p. 116.)

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At about the same date an engine was erected at Whitehaven, in Cumberland, for Mr., afterwards Sir, James Lowther. "A 'licence from the Committee of Proprietors in the fire-engine to Mr. James Lowther,' dated 22 February, 1726, recites that Thomas Newcomen, ironmonger, of Dartmouth, Devon, and others, by articles of agreement dated 10 November, 1715, Covenanted with Mr. Lowther to set up a fire-engine, with a steam barrel of at least 16 inches diameter within, and eight feet in length . . . and that such engine had accordingly been erected and since continued to be wrought there."[16]

Under the agreement of 1715, Mr. Lowther paid £182 per annum for the hire of the engine. By the agreement of 1726 he was, in consideration of the payment of a sum of £350, allowed to continue the use of that engine, or of another to be erected in its stead and having a cylinder not bigger than 22 inches diameter and 9 feet in length, at a peppercorn rent. It seems that upon the payment of a further sum of £100 he became the owner of the engine.

At the same period engines were being put up in the Newcastle-upon-Tyne district. Desaguliers tells us that Henry Beighton built an engine at Newcastle in 1718, and he refers to experiments made by Beighton on an engine at "Wasington." We have evidence that Beighton was staying at Felling, Co. Durham, in July, 1718. Now Felling is within a few miles of Washington on the river Wear, about nine miles south-east from Newcastle, and it seems probable that this was the site of the engine put up by Beighton. There is a local tradition that the first engine in the north was erected at a colliery on Washington Fell. The engine rapidly came into favour in the north, and in 1724 the Committee had a resident agent in County Durham, as appears from an advertisement in the *Newcastle Courant* for January 27th, 1724. "This is to give notice to all gentlemen and others, who have occasion for the fire engine or engines for drawing of water from the collieries &c. to apply to Mr. John Potter, in Chester-le-Street, who is empowered by the proprietors of the said fire engines to treat about the same."[17]

Soon after the appearance of this notice John Potter was engaged in the erection of an engine for Mr. Andrew Wauchope of Edmonstone, Midlothian. There were at least two engines in Scotland before this, but the Edmonstone engine is particularly important for the reason that we have in connection with it the full text of the agreement between the coal owners and the Committee of the Proprietors, and a full and detailed account of the expenses incurred in its erection.[18] The agreement is dated 1725; it gives by name the several members of the Committee appointed and authorised by the Proprietors of the Invention for Raising Water by Fire, *i.e.*, John Meres of London, Gentleman; Thomas Beake of

[16] The Victoria County History of the County of Cumberland, Vol. II., p. 354. (Mr. R. W. Moore on Coal Mining.)
[17] Brand, *History of Newcastle-upon-Tyne*, Vol. II., p. 686 n.
[18] Given in Bald's *A General View of the Coal Trade of Scotland*, 1812.

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the City of Westminster, Esq.; Henry Robinson, Citizen and Mercer of London, William Perkins of the City of Westminster, Tallow chandler; and Edward Wallin of London, gentleman. In consideration of an annual payment of eighty pounds payable quarterly at the dwelling house of John Meres in the Apothecaries Hall, Blackfriars, London, Wauchope was licensed to set up at his own expense and to work an engine of a certain size. Wauchope covenants that the engine shall be used to drain his own coal workings only, and that he will not drive ways underground in such a manner as to drain the workings of any adjacent owner; the servants of the Committee have the right to descend the pits to see that this covenant is being complied with, " and afterwards to ascend and come up from the said pits." The Committee undertake to furnish Wauchope with a cylinder, iron barrels, regulator, and other brass work upon the proper charges of the said Andrew Wauchope; the account of the expenses is, however, in the name of Potter: " An account of money paid for a Fier-Engin belonging to the Honourable the Laird of Edminston, by John Potter, Engineer," and it is John Potter who signs the acknowledgment of the receipt of the full sum of £1,007 11s. 4d. on July 1st, 1727, one of the witnesses being Abraham Potter, " my brother-german."

The agreement was for the term of eight years " until the full end and period of the said John Meres and proprietors aforesaid, their grant and license," that is to say until 1733 when the fire engine monopoly terminated in Scotland as well as in England. It will be noticed that Wauchope paid a royalty of £80, whereas Sir Richard Newdigate paid £150.

Mention has been made of the Potters—John and his brother Abraham. In 1722-24 another man of the same surname—Isaac Potter,—whether of the same family has not been determined, was engaged in erecting an engine at Königsberg in Hungary. Leupold[19] a contemporary German writer, gives a description and drawing of the engine and credits Potter with being its inventor. Leupold had not met Potter, nor had he seen the engine, and his drawing was prepared from descriptions by people who had seen it, but it is quite clear that it represents a Newcomen engine. The German author gives a letter dated Vienna, 23rd December, 1724, from which it appears that the engine had then been running continuously for nine months, and that Potter was still at Königsberg and had undertaken to remain there to superintend the engine. In recent years another drawing of this engine has been brought to light in the form of a copy made by hand in 1753 of an earlier drawing or print; it gives the date of erection of the engine as 1722, and names the engineer as Isaac Potter.[20]

At the same date as the Königsberg engine, another was being put up at Vienna, and still another at Cassel, but as to these very little definite information is forthcoming.

[19] J. Leupold, *Theatrum Machinarum Hydraulicarum*, 1725. Vol. II., p. 94.
[20] Conrad Matschoss: *Die Entwicklung der Dampfmaschine*, 1908. Vol. I., p. 309. *Zeitschrift des Vereines deutscher Ingenieure*, 1905. Vol. II., p. 1974.

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The year 1726 saw the Newcomen engine applied in London for the purpose of pumping water for a public supply. The York Buildings Water Works had been established in 1676 on the Bank of the Thames on a site at the lower end of Villiers Street, Strand, probably in part now covered by Charing Cross railway station. As in other early works for pumping up water from the Thames—Bulmer's at Broken Wharf, and Ford's at Somerset House—the pumps at first were worked by horse mills. An engine on Savery's plan had been erected in 1712, but this had proved a failure. The installation of the Newcomen engine, and indeed the affairs of the York Buildings Company generally, receive a considerable amount of comment in the newspapers and ephemeral literature of the period.

The company had been incorporated by Act of Parliament in 1691 as "The Governor and Company of Undertakers for raising Thames water in York Buildings," and it appears that in 1719 they raised a considerable capital for the purchase of estates in Scotland, forfeited in the rebellion of 1715, and on these estates they embarked upon coal mining and ironmaking. The year 1720, it will be remembered was the year of the South Sea Bubble and in common with other perfectly legitimate and sound undertakings the York Buildings concern became involved in a whirlpool of speculation; their ten pound shares went up to £305, and in the "South Sea Playing Cards" we find the following lines:—

"You that are blessed with wealth by your Creator,
And want to drown your money in Thames Water,
Buy but York Buildings, and the Cistern there
Will sink more pence than any fool can spare."[21]

The fire engine company itself seems to have become involved in the prevailing mania, for we take it that the following extracts[22] can refer only to the company which had acquired Savery's patent and Act of Parliament.

"Why must my stupid fancy e'er admire
The way of raising Water up by Fire?
That cursed Engine pump'd my Pockets dry,
And left no Fire to warm my fingers by."

The Broken Stock-Jobbers: Epilogue by a Loser, 1720

"Water Engine
Paid in ..... 4 pound.
Sold at ..... 50 pound.
Come all ye Culls, my Water Engine buy
To Pump your flooded Mines, and Coal-pits dry.
Some projects are all Wind, but ours is Water,
And tho' at present low may rise here a'ter."

The Bubbler's Mirrour, or England's Folly, 1721.

[21] Chancellor: *The Annals of the Strand*, 1912, p. 98.
[22] Both given by Mr. J. Eliot Hodgkin in *Notes and Queries*, 7S. Vol. V., p. 225.

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The contemplated erection of the York Buildings engine led to the publication of a burlesque production, which, as will be seen, went into a second edition,[23] bearing the title:—*The York Buildings Dragon, or a Full and true account of a most horrid and barbarous murder intended to be committed on Monday the 14th day of Febr. next (being Valentines-day) on the Bodies, goods and name of the greatest Part of His Majesty's Liege subjects, dwelling and inhabiting between Temple-Bar in the East, and St. James in the West, and between Hungerford Market in the South and St. Marylabonne in the North by a sett of evil minded Persons, who (by the Instigation of Plutus, and not having the fear of several Lords, Knights and Gentlemen before their eyes) to assemble twice a week, to carry on their wicked purposes, in a private room over a stable by the Thames side, in a remote corner of the Town.*

The second edition, augmented by almost Half London, 1726, (16 pp., 4to.).

The attention of the public being focussed on the York Buildings Water Works, the occasion was seized to issue an engraving of the engine as it was being constructed at this date. The publication is announced in the *Daily Post* of March 28th, 1726:—

> "Wheras the famous and useful engine for raising water by fire will soon be at work at the York Buildings Waterworks, in the Strand; there will on Wednesday next be published a true draft of the same, as it is at work in the several parts of great Britain, and proper explanation. Sold by John King at the Globe in the Poultry. Price One shilling."

There has been discovered at the British Museum a print lettered "The Engine for raising Water by fire," engraved by Sutton Nicholls, and dated by him 1725.[24] There seems to be no room for doubting that this print is that which is referred to in the advertisement. It was copied by Weidler, a German writer, within a few years of its publication, and is referred to by him as having been engraved by Sutton Nicholls and sold by John King. The advertised price seems low, but it is not unlikely that the engraving was published under some arrangement with the Proprietors of the Invention, who for their own purposes may have ordered a considerable number of copies.

The Newcomen engine at York Buildings appears to have worked successfully, but the cost of fuel was found to be very high in proportion to the work done. Newcomen's friend, Dr. Allen, stated that it amounted to at least £1,000 a year.

Necessarily, in view of the cost of carriage, the fuel would be an item of considerably greater importance in London than it was on the coalfields, and, at

[23] The first edition appeared in December, 1725, price 6d. It is reprinted from *Read's Weekly Journal* of Dec. 18, 1725, in Wright's *Caricature History of the Georges*, p. 45.

[24] The print was reproduced in *The Engineer*, Aug. 11th, 1905. The discovery of the advertisement, and the identification of the print, are due to Mr. R. B. Prosser.

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least in part, on this ground the use of the Engine was discontinued in 1731.[25] It remained in position, however, for some years and appears to have been exhibited to curious visitors. In an account of London published in *All Alive and Merry; or the London Daily Post* of Saturday, April 18, 1741, we have the following notice of it:—

"There is a famous machine in York Buildings, which was erected to force water by means of fire, thro' pipes laid for that purpose into several parts of the town, and it was carry'd on for some time to effect; but the charge of working it, and some other reasons concurring, made its propriteors, the York Building Company, lay aside the design; and no doubt but the inhabitants in its neighbourhood are very glad of it; for its working, which was by sea-coal, was attended with so much smoke, that it not only must pollute the air thereabouts, but spoil the furniture."[26]

The first engine in France was set up, at Passy near Paris, at about the same time as the York Buildings engine. It is described and illustrated in *Machines et inventions approuvées par l'Académie Royale des Sciences*, Vol. 4. In the French accounts of this engine it is said to be by MM. Mey and Meyer. Mey, however, was one John May, an Englishman, probably a resident in Paris, and Meyer, without doubt, was John Meres, one of the Committee of the Proprietors of the Invention. *In the Report of the Historical Manuscripts Commission* on the MSS. of the Earl of Egmont (VII. p. 248) is a letter, dated Paris, May 4, 1726, from D. Dering to Lord Percival, in which it is stated that:—"The writer went to see Mr. Meres' fine engine at Passy. A cord and a half of wood serve 24 hours, and it throws out of three pipes, 24 inches wide, near 16 muids of water in a minute. Meers computes that when going to perfection it casts about 25,000 muids in 24 hours. Captain Savery in England gave the first hint of this machine."

It appears from his will, which was proved June 6th, 1726, that Meres died in Paris soon after the interview recorded above.

At about the same date, 1726, it is said that an engine was erected in Toledo and another in Sweden, the latter by Marten Triewald, a Swede, who had spent several years at the coal mines of Newcastle.

[25] Towards the year 1730 the affairs of the York Buildings Company had become much involved. In 1732-35 they were the subject of a Parliamentary enquiry, and a series of reports by a Committee of the House of Commons show bad management if nothing worse. In the Report of the year 1733 (House of Commons Reports, Vol. I., p. 581) is "An account of the Debts of the York Buildings Company, due at Christmas, 1732," in which are included:—

A bond to James Wilkinson for the Waterworks account	£1800	0	0
Interest due at Christmas at £4 per cent.	144	0	0
A bond to the Proprietors of the Fire Engine, ditto account	787	10	0
Interest to Christmas at £4 per cent.	40	10	0
Maltis Royal for Coals to the Fire Engine	660	15	0

[26] Wright: *Caricature History of the Georges*, p. 45.

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Newcomen lived to see his engine employed in the mines of most parts of England, in Scotland, and on the Continent. Whether he derived any pecuniary benefit from his invention we do not know, but it is fairly certain that if he did it was on quite a small scale, and not in any way commensurate with the value of his work. He had not a patent, so that, in the ordinary course, such advantage as he might expect to derive from it would be merely his profit as an engine builder, and as a builder he could not expect to have the field to himself for any length of time. By 1715, the time of the death of Savery, whose engine had been tried and found wanting, that of Newcomen had been set up at Dudley Castle and probably at two or three other places, but there is no indication that Savery made any claim that it came within his patent, and even in November, 1715, we find Newcomen entering into an agreement with Mr. Lowther which deals only with the hire of an engine, and makes no reference to the payment of a royalty. The death of Savery, however, marks a turning point; it was then that his patent was acquired by "The Proprietors of the Invention for raising water by fire." This was a company of business men, and they set out to make such profit as they could upon their investment, and it is clear from the advertisement in the *London Gazette* that by August, 1716, they had asserted their rights and were demanding the payment of royalties on the engines made by Newcomen. Later on the evidence shows that they were receiving royalties, but whether this was by a voluntary arrangement on the part of Newcomen, whether he himself regarded his invention as an improvement upon Savery's, or as coming within the terms of Savery's patent and Act, or whether he had been coerced by the threats of a powerful syndicate, or by actual litigation, are unsolved problems. It is quite possible that it may have been held that Savery's grant included not merely the particular apparatus which he had devised, but all other methods of raising water by fire. The Committee would very naturally take such a view, and foster the idea that they were working Savery's invention, see, for instance, the concluding remark in Dering's letter about the engine at Passy, quoted above. The Newcomen engine is ascribed to Savery by Dr. Dalton, Dr. Erasmus Darwin, and other writers.

It may be asked—to what extent was Newcomen an original thinker? Did the principle of the engine—the condensation of steam under a piston—originate with him? Briefly, the sequence of ideas may be set forth thus: In 1654, Otto von Guericke, of Magdeburg, carried out an experiment to show the pressure of the atmosphere, in which he used a cylinder and piston; he connected the piston, by a rope passing over pulleys, to a heavy weight; then, by means of a small air-pump worked by hand, the air was exhausted from the cylinder, whereupon the weight was lifted by the pressure of the atmosphere upon the upper side of the piston. In 1678-79 Huygens essayed to apply this idea to a motive power engine, and constructed an apparatus in which a vacuum was produced under a piston by the

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explosion of gunpowder. Papin in 1687 developed further the application of gunpowder, and then, in 1690, he proposed to produce the vacuum by the condensation of steam. To Papin then belongs the distinction of first giving to the world the principle of the atmospheric engine. Whether Newcomen became acquainted with this proposal of Papin, or whether he arrived at it independently, we do not know. The apparatus devised by Papin for carrying out the idea was of a very crude character, and, while perhaps suitable for laboratory purposes, was altogether unsuitable for use as an engine. Newcomen, on the other hand, embodied the idea in a practical form, and produced a successful engine. It is by no means easy for us to-day to realise the difficulties which Newcomen had to surmount. Mechanical engineering as we understand it had not come into existence. Smiths had attained to a high degree of skill in their craft, but workmen for other branches were untrained; while the range of materials available for construction was quite limited. Newcomen grasped what it was possible to do under the existing conditions, and he devised a machine which it was possible to build with the materials, tools, and men at his disposal; a machine which, when built, worked successfully.

Upon the expiry of the fire-engine Act, which took place in 1733, four years after the death of Newcomen, the use of the engine grew apace. In 1765 James Watt invented the separate condenser. This improvement, according to which the steam, instead of being condensed in the engine cylinder, was condensed in a separate chamber, resulted in a very considerable saving of fuel; but engines of the Newcomen form continued to be built long after this, and at least one of them is in use to the present day.

The labours of James Watt brought the steam engine to a high pitch of perfection, both as to economy in operation, and to mechanical construction, but it would seem that his admittedly great merit has been allowed, in the public estimation, to overshadow the pioneer work done by Thomas Newcomen.

CONCLUDED.

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Appendix.

NOTES ON THE GRIFF ENGINES FROM THE BOOKS AND PAPERS AT ARBURY, NUNEATON.

From the coal-pit accounts, 1722-27:—

			£	s.	d.
Fire-engine rent					
1723.	3d July.	To Mr. Mears & a note	100	0	0
		Paid Mr. Mears's Bill for drawing ye writings, &c.	5	10	0
172⁴/₅.	9 Jan.	To Mr. Meres	50	0	0
	20 ,,	More	100	0	0
1725.	16th June.	in full to Xmas, 1724	50	0	0
	10 Aug.	to him	50	0	0
1726.	May 21st	To Mr. Dutch[1] in full to Xmas, 1725	250	0	0
		in part from Xmas	20	0	0
			£625	10	0

From a list of yearly totals of the Coal pit accounts, 1722-27:

Engine rent 4 years at Mids., 1727	1150	0	0

From other account-books:

The fire-engine rent for 3 qrs. due at Lady Day, 1728	225	0	0
To a years Rent for 2 engines at Lady Day, 1729	300	0	0
for ½ year at Michmass, 1729	150	0	0

Entries relating to the sale of the engines:

Receipts:

		£	s.	d.
1729.	Mr. Pilkington for a Brass Cillender	40	8	0
1731.	Mr. Green for Boyler & Cillender	58	0	0
1732.	Mr. Green for materials belonging to ye fier engine	3	8	6
1733.	James Morrice for old geers at ye Engine	0	5	0
1734.	Lead in part from the fier engine	15	0	0
	Iron ,, ,, ,,	10	0	0
	Lead from the fier Engin	3	0	0
	John Wise for a Cillender	23	0	0

Payments:

1729.	Expenses selling & delivering ye Brass Cillender	0	14	2
	To Carriage of it to Mesham	0	12	0
	Expenses receiving ye money	0	3	6
1732.	Expenses selling Boyler & Cillender	0	4	0
	Expenses at Coventry receiving ye money for them	0	2	0
	Expenses receiving ye remdr at Bedworth	0	2	0
	To Mr. Townesend for assistance in selling them	0	5	0
	To, Richd. Hardy share for taking down engine	4	4	0
1734.	Spent selling the last fier engine	0	5	0

Expenses in setting a new boiler, 1728.

Week ending Sept. 21, 1728:

Six bricklayers 28 turns putting in ye new Boyler at Lower Engn at 1/6	2	2	0
Men & lads 55 turns serving them	2	10	0
Drink for bricklayers & Servers	0	18	6

[1] Meres died in 1726; Cornelius Dutch was one of his executors.

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Supplementary Note
on
Beighton's Drawing of Newcomen's Engine, 1717.

It has been explained in the body of the preceding paper that a hitherto unknown engraving of a Newcomen engine has recently been discovered in the Library of Worcester College, Oxford, by Mr. L. de H. Johnson of the Oxford University Press. By the courtesy of the Provost of the College the Rev. F. J. Lys, M.A., we are enabled to issue a facsimile of the engraving. In view of the historical value of this find the Council has deemed it advisable to have the engraving reproduced in collotype of the exact size of the original and to make use of it as the frontispiece.[1]

It will be observed that the print is inscribed: "To the Honble. Geo. Clark." George Clarke (1660-1736) was well known as a Fellow of All Souls, and as a statesman, having been Secretary at War from 1692 to 1704 (*see* D.N.B.). He is remembered by his benefactions to Oxford and in particular the foundation of Worcester College owes much to him. To it he gave many of his books and MSS; the album which contains the engraving under consideration is part of this gift. The docket on the print "Rd. from Mr. Beighton, Septr. 16th, 1718," is in Clarke's handwriting.

As remarked in the paper, till the discovery of this engraving, the earliest known representation of Newcomen's engine was Barney's print published in 1719. Apart from its position in point of time we are inclined to place the engraving on a higher plane than the print of Barney, because it is the work of a scientific man who thoroughly understood what he was delineating, whereas we do not know what was Barney's material.

The succeeding print in point of date is that of Sutton Nichols, 1725, and then we have illustrations in Desaguliers's *Course of Experimental Philosophy*, 1734. It is evident by inspection that Beighton's drawing is the foundation on which Nichols worked and also that, with the exception of the valve gear, Desaguliers's illustration is an exact copy. Now the latter author definitely states that the engine he depicts was that erected at Griff in Warwickshire and that the particulars of it were supplied to him by Beighton. The inference is clear that Beighton, a native of Griff and a friend of the Newdigate family, had measured up and made a drawing of the engine there, and that within a year or two of its erection by Newcomen.

It will be observed that the several parts on Beighton's drawing are designated by letters. Unfortunately, however, no letterpress accompanies the engraving at Worcester College, but as the letters agree almost exactly with those given by Nichols and by Desaguliers, the legend below has been prepared with their aid.

[1] The size of the paper has necessitated folding, but separate copies, flat or rolled, can be had from the Hon. Secretary at a small cost.

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Legend of Beighton's Drawing.

A. Fireplace.
B. Boiler and seating.
C. Cylinder with piston.
D. Steam pipe from boiler to cylinder.
E. Steam cock or regulator.
F. Puppet clack or safety valve.
G. Gauge pipes to show when the level of the water in the boiler is too high or too low.
H. Buoy pipe; the shank of the buoy when the steam becomes strong forces up the lever R and interceptor 7 thereby lifting the notch from the lever of the injection cock which is opened by the fall of the weight 3. The tail 1 of the lever is restored by a pin in the plug rod.
I. Standpipe for shank K, to indicate height of water in boiler.
K. Float in boiler.
L. Shank of the piston.
M. Injecting pipe bringing cold water from cistern g.
N. Injecting cock.
O. Lever or spanner of injecting cock.
P. Two standards supporting the Y to work the regulator; 4 and 5 are arms to work the Y by pins in the plug rod; 6 is a strap to restrain the Y.
Q. Working beam or plug rod.
R. Lever, one end of which turns on a pin and the other is attached to the interceptor 7; the lower end of this is attached to the notched lever 2 that releases the injection cock.
S. Counterweight to lever R.
T. Eduction pipe.
V. Overflow pipe from top of cylinder and from snifting valve.
W. Pipe supplying boiler with water from top of piston.
X. Snifting valve.
Y. Waste well.
Z. Pipe supplying water from cistern g to top of piston.
aaaa. Four great beams supporting the engine and the floor of the house.
bcde. Ground floor of the house.
f. Chimney.
g. Cistern of cold water to supply injection.
h. h_2. Great lever or beam.
i. Rod and chain fixed to the outer end of the beam working pumps from the bottom of the mine.
k. Small force pump supplying cistern g.
l. Windlass and rope, whereby men and materials are conveyed up and down the pit.
m. Pipe by which pump K supplies cistern g.
oooo. Outline of boiler.

It has been mentioned above that the valve gear is the one point of difference between the print and the representation by Desaguliers. Further research is needed on this point and it is hoped a communication may be made to the Society on the subject of atmospheric engine valve gear in general. R.J.

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A Link with Newcomen.

On Thursday, Dec. 11th, 1924, an old fire-grate associated with Thomas Newcomen came under the auctioneer's hammer at Dartmouth, where Newcomen was born in 1663. Although of such historical interest to the town, the Councillor who was present at the auction only bid 5s., and the relic was secured by a private buyer for 37s. 6d. The grate had been incorporated in a house which the late Mr. Thomas Lidstone, the county surveyor, built on Ridge Hill, Dartmouth, in 1868, and named Newcomin Cottage, because it contained a good deal of material which its owner had retrieved when Newcomen's house in Lower-street was demolished.[1]

In Memory of Trevithick.

An interesting event occurred on Wednesday, July 9th, 1924, when a small party of American engineers and their ladies, who were in London for the World Power Conference, spared a day from their limited time to go down to Dartford to lay a wreath on the tablet to the memory of Richard Trevithick in Dartford Parish Church—a graceful act inspired by Mr. Fred R. Low, President of the American Society of Mechanical Engineers, Member of this Society, and Mr. R. C. Beadle, Assistant President of the International Combustion Engineering Corporation, New York.

The party was under the guidance of Mr. E. Kilburn Scott, and was met at Dartford by representatives of the Urban District Council and of the firms of Messrs. J. & E. Hall and Messrs. Vickers, Limited. Luncheon was provided for the party at Messrs. Vickers Works by Mr. W. A. Dixon, following upon which an eulogy on Trevithick was pronounced by Mr. A. H. Batten.

The wreath, which was deposited by Mrs. Low, bore the following inscription:

TO THE MEMORY OF RICHARD TREVITHICK
BORN ILLOGAN, CORNWALL, APL. 13, 1771
DIED DARTFORD, KENT, APL. 22, 1833
ON THIS, THE OCCASION OF THE FIRST WORLD POWER CONFERENCE, IT IS MEET THAT WE SHOULD REMEMBER THOSE WHO HAVE PIONEERED IN ENGINEERING, PARTICULARLY THOSE WHO EARLY STRUGGLED WITH THE PROBLEMS OF STEAM TRANSPORTATION, WHICH STILL STANDS AS THE FIRST GREAT FACTOR IN BRINGING PEOPLES TOGETHER IN TRADE AND UNDERSTANDING

We are indebted to Mr. Kilburn Scott for the illustration of the Trevithick memorial that accompanies this note (*see* Plate XXI).

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[1] c.f., p. 116.

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Analytical Bibliography
of the
History of Engineering and Applied Science

PART III.

The "Beiträge zur Geschichte der Technik" is here again abbreviated, to *B.G.T.* I have to acknowledge with thanks the continued help of Mr. A. A. Gomme and our Honorary Secretary, and should welcome from other Members notes of articles of historical interest in periodicals.—E.W.H.

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Report of the Council for the Session, 1923-24.

Presented at the Annual General Meeting, Nov. 12th, 1924.

The Council has pleasure in submitting the Annual Report for the Session 1923-24.

The Session just concluded was one of growth and widening activities. The total number of members on the roll of the Society at its close was 165, and 30 libraries and Institutions are now taking the Transactions. The number of new members elected during the session is 26; of these six live in America and two in Australia. The position of the Society in the North American continent is very gratifying. There are now no less than 28 members in that part of the globe, and in recognition of that fact the Council co-opted Mr. Charles Penrose, of Philadelphia, a Member of Council. Mr. Penrose has been very active in promoting the Society's interests in the United States.

The Council records with regret the death of three members, Dr. W. H. Maw, Mr. E. Butt-Gow, and Eng.-Comm. Leslie Robertson, R.N. Six members have resigned for various reasons, some apparently because they are not in full sympathy with the work of the Society.

Six meetings were held during the session, five in London and one—the Summer Meeting—at Coalbrookdale, Shropshire. The papers presented were as follows:—

Presidential Address. "The Value of the History of Technology." Loughnan St. L. Pendred, M.I.Mech.E. October 26th, 1923.

"The Dynamics of Leonardo da Vinci." Ivor B. Hart, D.Sc., Ph.D. December 6th, 1923.

"A Chain of Pots of the 6th to 7th Century A.D." G. F. Zimmer, A.M.Inst.C.E. February 6th, 1924.

"A Dredger of the Chain Pump Type of 1560." G. F. Zimmer, A.M.Inst.C.E. February 6th, 1924.

"A 16th Century Tread-Wheel for Raising Water." H. A. Sandford. M.A., F.G.S. February 6th, 1924.

"Notes on Evelyn's 'Circle of Mechanical Trades,' 1660." A. Forbes Sieveking, F.S.A. February 6th, 1924.

"The Rastricks—Civil Engineers." H. W. Dickinson and A. Lee. March 5th, 1924.

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"Memorandum on the Four Locomotives imported into America in 1829 by the Delaware and Hudson Company. L. F. Loree. March 5th, 1924.

"Works Organization in the Seventeenth Century. Some Account of Ambrose and John Crowley." W. A. Young. April 9th, 1924.

"A Sketch of the Industrial History of the Coalbrookdale District." Rhys Jenkins. June 19th, 1924.

"Some Notes on the Shropshire Coal and Iron Fields." A. Titley, M.I.Mech.E., and J. W. Hall, M.Inst.C.E. June 19th, 1924.

"The Discoveries of the Darbys of Coalbrookdale." T. S. Ashton, M.A. June 19th, 1924.

It will be observed that on several evenings more than one paper was presented. This experiment was tried in the second session, and proved attractive to Members, and was therefore repeated. The fact that one of the papers was contributed by an American Member is a source of much satisfaction to the Council, and it trusts that Mr. Loree's paper will be the forerunner of many more contributions from abroad. The papers mentioned above will appear in the "Transactions" in due course; only it must be noted that the last two, viz., those presented at the Summer Meeting, could not, owing to lack of time, be properly read or discussed, and were accordingly reserved for the first meeting of the present Session.

The meeting held on December 6th, 1923, was the Annual General Meeting. No change took place in the constitution of the Council, as all the retiring members were re-elected. The Summer Meeting lasted over two days, June 19th and 20th, with headquarters at Shrewsbury. It was well attended, and was a decided success.

As in previous years, so in this, the Society has acted as a clearing house for information, both between members and with the outside public.

The financial position of the Society is strong, as will be judged by looking at the Accounts and Balance Sheet. It must be noticed, however, that the cost of printing the Transactions, Volume III., roughly £130, ought to have been charged on this year's accounts, and would have been so charged had not delay occurred in producing the volume. But even when this adjustment is made, the Council is not far from the time when it will feel justified in bringing out, as it has long wished to do, some extra publication.

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NEWCOMEN SOCIETY.

Revenue Account from 1st October, 1923, to 30th September, 1924.

Dr.

Expenditure.	£	s.	d.	£	s.	d.
To Hire of Rooms and expenses of Ordinary and Summer Meetings	18	4	10			
Printing and Stationery, including preparation of Transactions	32	8	7			
Typing and Mimeographing and clerical assistance	15	0	6½			
Postages, Telegrams, Parcels, Stamps, and Travelling Expenses	10	10	9½			
Bank charges and commission		4	11			
				76	9	8
Excess of Income over Expenditure				197	4	4
				£273	14	0

Cr.

Income.	£	s.	d.	£	s.	d.
By Subscriptions and Donations for the year	196	0	9			
Members' and Visitors' contributions to the Summer Meeting	12	1	0			
Sale of Transactions and Binding	62	15	11			
Bank Interest to September 30th	2	16	4			
				273	14	0
				£273	14	0

Balance Sheet as at September 30th, 1924.

Liabilities.	£	s.	d.	£	s.	d.
Balance brought forward from October 1st, 1923	115	0	6½			
Surplus from Revenue Account, year ending September 30th, 1924	197	4	4			
				312	4	10½
				£312	4	10½

Assets.	£	s.	d.	£	s.	d.
Cash as under :—						
On deposit at Bank	170	0	0			
On current account	137	11	3			
In Treasurer's hands	4	13	7½			
				312	4	10½
Stock of "Transactions" not valued ...				—	—	—
				£312	4	10½

The above Accounts have been examined with the Books and Vouchers, and found correct.

(Signed) A. M. BUSHELL, *Hon. Auditor.*

(Signed) E. A. FORWARD, *Treasurer.*

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The Newcomen Society

For the Study of the History of Engineering and Technology

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JANUARY, 1925.

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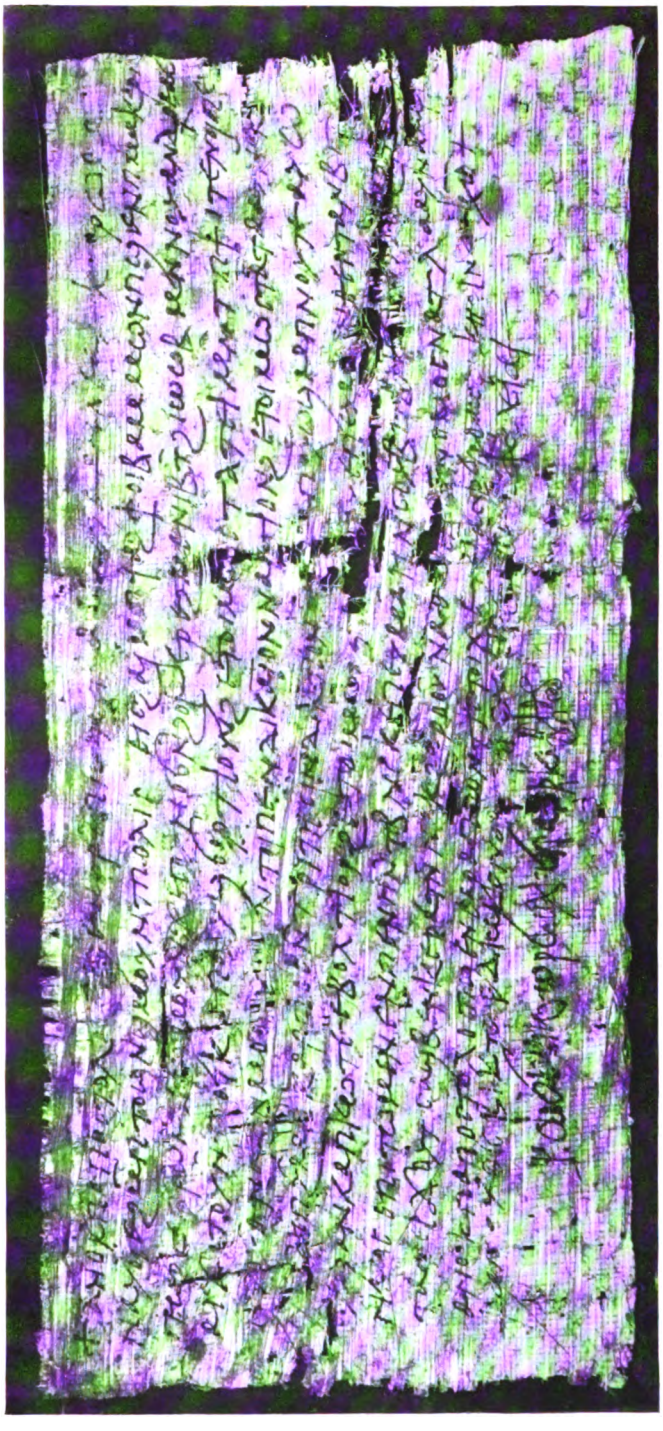
PLATE I.



AGREEMENT FOR HIRE OF CHAIN-OF-POTS, SIXTH CENT. A.D.
From the original papyrus in the Library, University of Bâle.

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PLATE II.

CHAIN PUMP DREDGER c. 1560.
after the original drawing by Pieter Brueghel
in the possession of the Duke of Devonshire.

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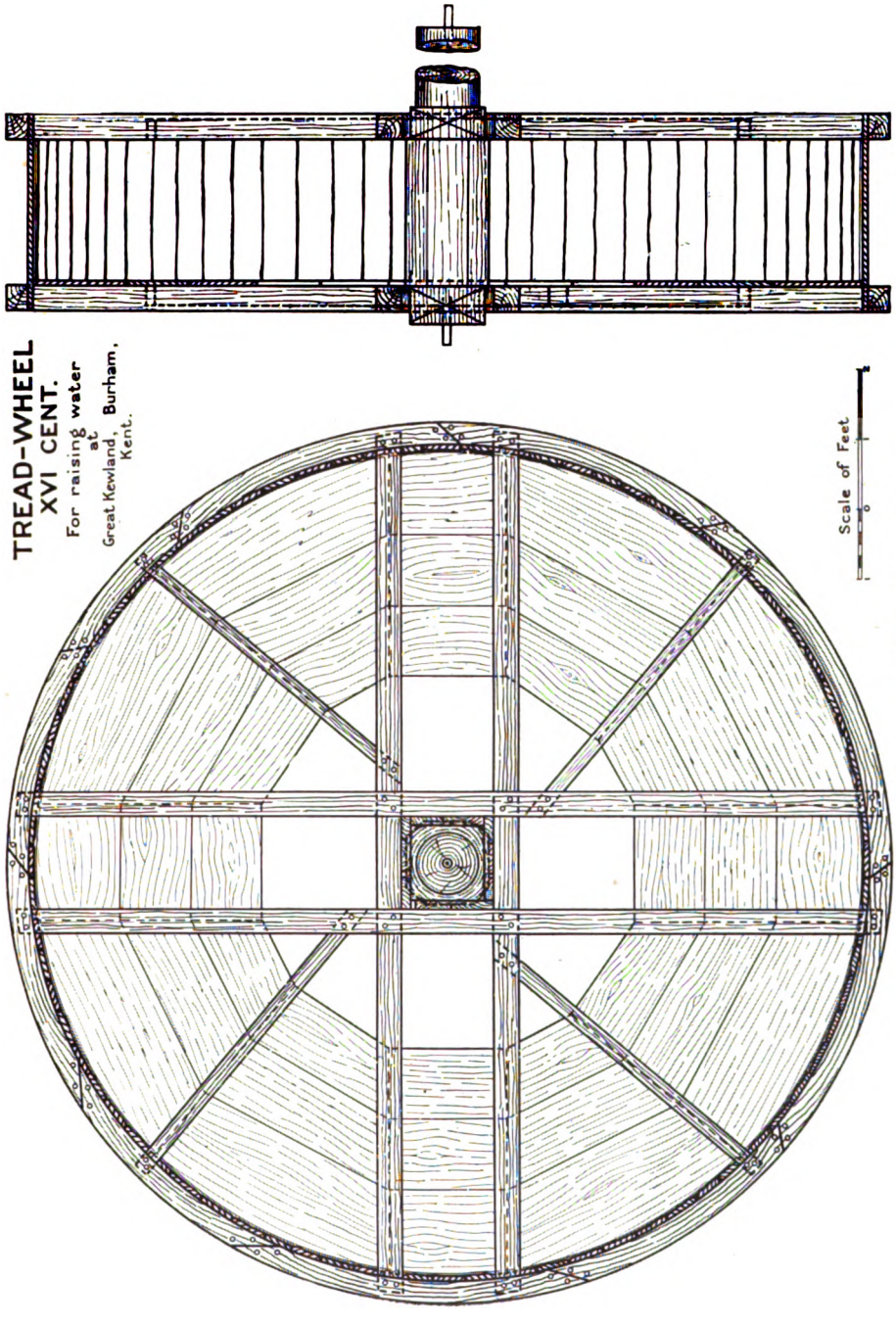
PLATE III.



TREAD-WHEEL FOR RAISING WATER
at Great Kewland, Kent.

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PLATE IV.

TREAD-WHEEL FOR RAISING WATER
at Kensworth, Hertfordshire.

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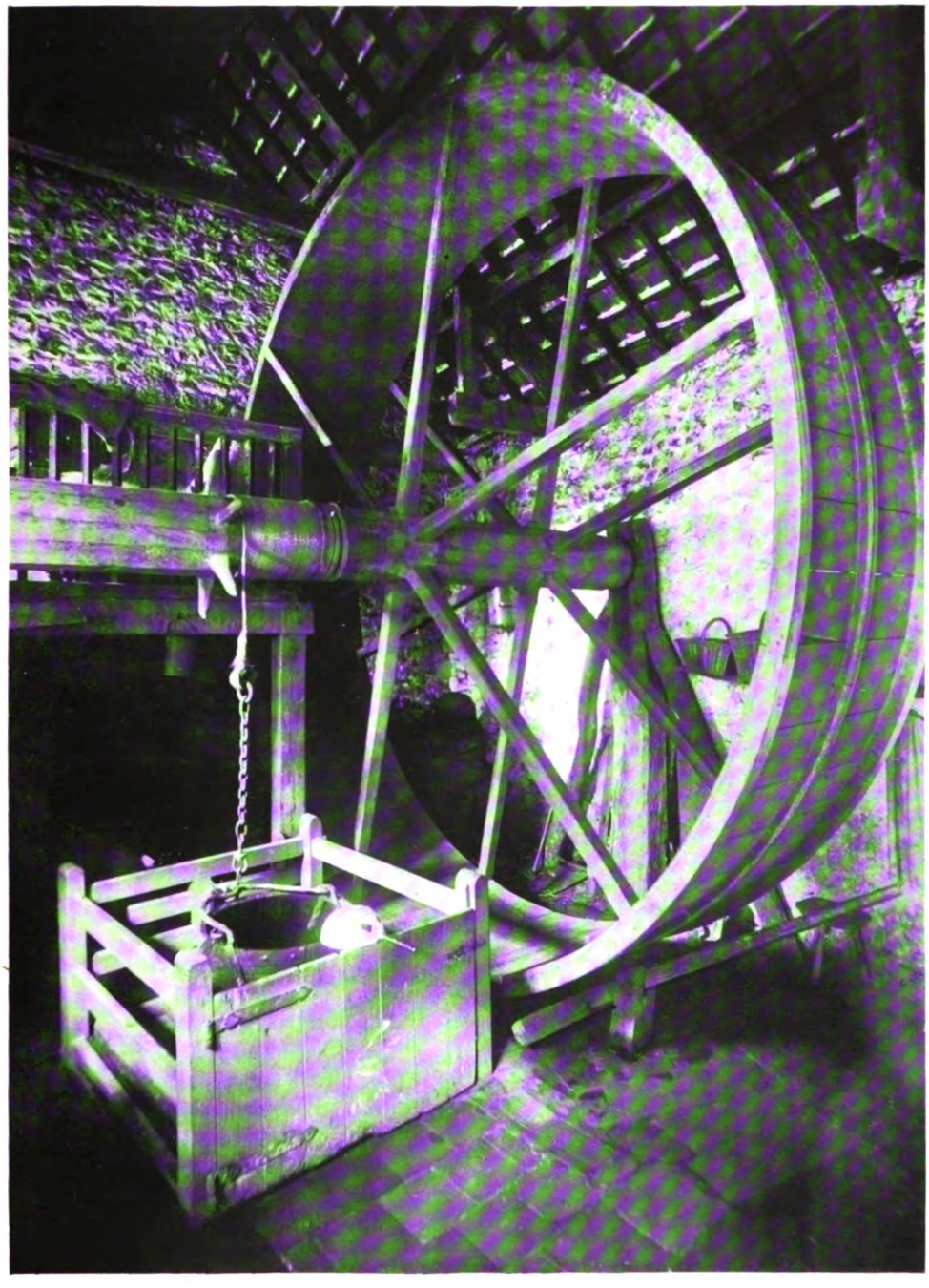
PLATE V.



TREAD-WHEEL FOR RAISING WATER
at Beer, Devonshire.

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PLATE VI.

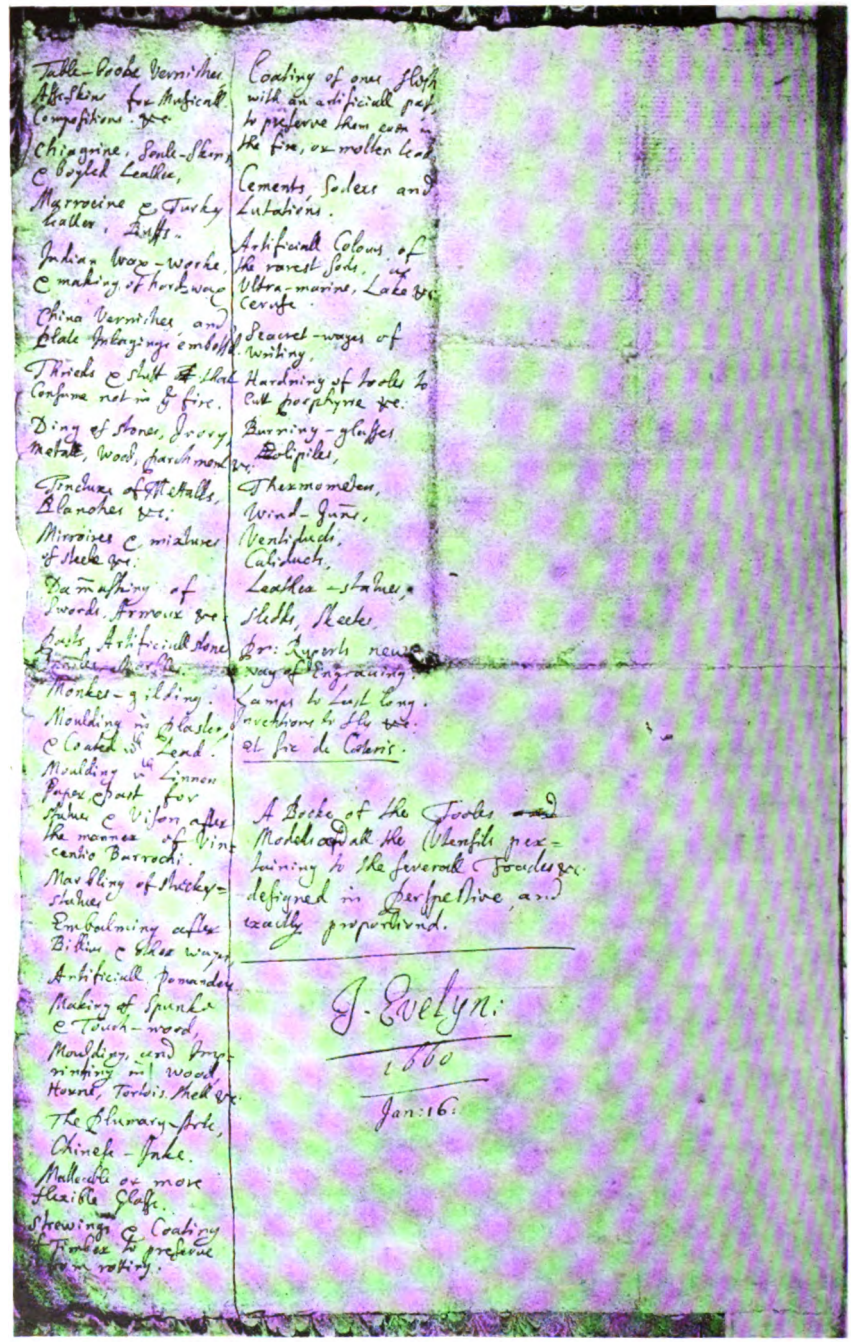

Table-Booke Vernishes
Asse-Skins for Musicall
Compositions &c.
Chiagrine, Soule-Skins
& boyled Leather,
Marrocine & Turky
leather, Buffs.
Indian Wax-worke,
& making of hard wax
China Vernishes and
Plate Inlayings embossed.
Thrieds & stuff that
Consume not in ye fire.
Ding of stones, Ivory,
Metall, Wood, parchment &c.
Tincture of Metalls,
Blanches &c.
Mirroires & mixtures
of steele &c.
Damasking of
Swords, Armour &c.
Pasts, Artificiall stone
Jewelles, Marbles.
Monkes-gilding.
Moulding in plaster,
& Coated wth Lead.
Moulding wth Linnen
Paper, & past for
statues & Visors after
the manner of Vin-
centio Barrochi.
Marbling of Stucky-
statues
Embalming after
Billius & other wayes
Artificiall Pomanders
Making of Spunks
& Touch-wood,
Moulding, and Imp-
rinting in wood
Horns, Tortois, Shell &c.
The Plumary-Arte,
Chinese-Inke.
Malleable or more
flexible Glasse.
Strewings & Coating
of Timber to preserve
from rotting.

Coating of ones flesh
with an artificiall past,
to preserve them even in
the fire, or molten lead.
Cements, Sodees and
Lutations.
Artificiall Colours of
the rarest Sods, as
Ultra-marine, Lake &c.
Ceruse.
Seacret-wayes of
writing.
Hardning of tooles to
cut porphyrie &c.
Burning-glasses
Polipiles,
Thermometers,
Wind-Guns,
Ventiducts,
Caliducts,
Leather-statues,
Sledds, Skeetes,
Pr: Ruperts new
way of Engraving.
Lamps to Last long.
Inventions to fly &c.
et sic de Cæteris.

A Booke of the Tooles and
Models and all the Utensils pertaining to the severall Trades &c.
designed in Perspective, and
exactly proportioned.

J. Evelyn:
1660
Jan: 16:

EVELYN'S MS. "CIRCLE OF MECHANICAL TRADES."
Last page.

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PLATE VII.

By His Majesty's Royal Letters Patent.

J. RASTRICK,

ENGINEER, MILL-WRIGHT, PUMP AND PATENT CHURN MAKER,

MORPETH, NORTHUMBERLAND,

DRAWS Plans in the moſt accurate Manner; alſo executes the Workmanſhip of the various and moſt uſeful Machines for manufacturing Grain, Iron, Woollens, Linens, and Cottons; Saw, Paper, Oil, and Snuff Mills, with improved Machines for thraſhing Corn; Breweries; Diſtilleries; Hydraulical Engines, wrought by living, natural, or artificial Powers; Cranes; Pile Engines; Bridges; Piers; Quays; Dam-heads; Caſcades; and Fiſhing Locks.—Alſo Steam Engines on a new Conſtruction; with many others too tedious to mention.

J. R. having conſtructed the ſeveral Machines above-mentioned in *South* and *North Britain*, begs Leave to return Thanks for all paſt Favors, and ſolicits a Continuation of the ſame.

PROPERTIES OF THE IMPERIAL CHURN.

Amongſt the Variety of uſeful Machines, there is none of more general Utility than the Churn; and every Attempt to facilitate the Labour, and render ſhorter the Time of its Operation, muſt therefore be highly deſerving of public Encouragement. The *Imperial Churn* poſſeſſes thoſe Properties in an eminent Degree, by not only reducing the Labour to an eaſy Employment for one Perſon, which the other Churns, of equal Size, make hard Work for two, but alſo ſhortens the Time of its Operation with equal Succeſs; but what more eſſentially recommends it in Preference to all other Churns, is, that inſtead of heating the Cream, by increaſing the Velocity, it has the contrary Effect, that of cooling it in Proportion to the Increaſe of Motion, and conſequently prevents that diſagreeable Bitter always obſerved in Butter that is overheated in the Time of churning. This Bitterneſs being much owing to the Action of the Acids in the Cream during the Time of its forming into Particles of Butter, the longer Time it takes in churning, gives the Acids more Time to act: and therefore, the ſooner it is churned, muſt render the Butter ſweeter and finer flavoured. Every Year the Complaint of Hot-churning, &c. becomes more general, which is the Occaſion of ſo much bad Butter: It is greatly owing to ſo much new Land, whoſe Herbage is of ſo tender a Quality, that it ſoon receives Damage, by not diſcharging the fixed Air and Acids, which the *Imperial Churn* does. The Butter that is affected in this Manner will have white Scairs, or be of different Colours.

DIRECTIONS FOR MANAGING THE IMPERIAL CHURN.

To ſeaſon it, mix two or three Quarts of quick Lime amongſt ſome Water, and let the Mixture remain in it for three Days; turn the Works about frequently each Day, and when taken out cleanſe the Churn well with hot Water.—Repeated Scaldings will then fit the Churn for Uſe.

The Churn is to be hung upon a Frame with the Mouth up, a Pin to be put through the Frame into one of the Croſs-Bars, on the contrary End to the Handle, to prevent the Churn from turning round during the Time of churning. The Ventilator and Churn have a correſponding Mark, in order to fit the former exactly into the Mouth of the latter. The Ventilator is a great Preſervative againſt hot churning, by receiving the ſweet Air in the one Side, and diſcharging the ſour or bitter Acids on the other. In cold Weather it is very neceſſary to ſcald the Churn with boiling Water before uſing it, and to throw a Cloth over the Mouth of the Ventilator to prevent too much cold Air from entering.

After the Particles of Butter begin to unite, the Hand muſt be kept turning backward and forward, for a half Round, to gather the Butter; when done, the Mouth of the Churn is turned to one Side. By turning the Hand round, the Breakers will bring the Butter to the Mouth of the Churn. There is one or more of the ſmall Breakers left out for the Convenience of putting the Hand into any Part of the Churn, if required.

The firſt churns from one-half to five Pounds of Butter at a Time: Second from ditto to ten Pounds: Third from ditto to twenty Pounds: Fourth from ditto to forty Pounds: And the fifth from ditto to fifty two Pounds.

JOHN RASTRICK'S TRADE CIRCULAR, *c.* 1794.

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PLATE VIII.

JOHN RASTRICK,
Ætatis suæ 60.

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PLATE IX.

FORM OF THE

CEREMONY

FOR OPENING

CHEPSTOW BRIDGE,

On Wednesday, 24th July,

1816.

Company to assemble in the Square at One o'Clock.

THE PROCESSION.

A PAIR OF COLOURS.

ENGINEER & SURVEYOR.

Workmen in Divisions according to their Order, walking two and two.

A PAIR OF COLOURS.

Band of Music.

Solicitor.

Magistrates walking abreast,

SENIORS IN THE CENTRE.

Gentlemen, Farmers, Tradesmen, and others, who may chuse to join in the Procession, walking two and two.

When the Engineer and Surveyor arrive at the Bridge, to face about, and order all the Workmen to separate, and form a straight line from each Pillar of the Wing Wall; Colours dividing also, taking their Stand one at each Pillar.

The Workmen to remain stationary till the return of the Magistrates and the other Colours. Band playing, Procession to advance through the Line of Workmen.

On the Magistrates coming within the Wing Walls of the Bridge, a Gun to be fired as a Signal for the Bells to commence ringing.

The Procession to pass the Bridge—Band playing—Engineer and Surveyor taking the lead.

The Magistrates having advanced to the End of the Bridge on the Gloucestershire Side, to separate from the Procession, attended by the Engineer and Surveyor to view the Work. Company to remain on the Bridge forming a Line on each Side, until the Magistrates and their attendants return.

Magistrates, with the Surveyor and Engineer, having viewed the Work, rejoin the Procession, and proceed in order as at first to the Centre of the Bridge—Band playing.

Procession to halt: Magistrates to take their Station, each in their respective Counties—Now to declare their Approbation of the Work, and congratulate each other that the arduous Undertaking is completed.

THREE CHEERS,

Procession to return in the same Order, Engineer and Surveyor taking the lead, passing through the Line of Workmen, who are to rejoin the Company immediately behind the Gentlemen and others, walking in the same order.

The Carriages to take their Station on the Gloucestershire Side of the Bridge, and follow the rear of the Procession, and when they arrive at the Square, to draw off to the front Street, forming a Line thereon.

The Procession having returned to the Square to form two Lines facing each other; the Colours to join at the head of the Band, who are to march through the Lines thus formed playing

God Save the King.

Having passed down the Lines, and returned to the top of the Square, to halt, (Still playing) and after repeating the Loyal Tune thrice to Stop.

Magistrates and Company to give THREE CHEERS. Arrest, and Workmen to return the same.

END OF THE CEREMONY

MAJOR, PRINTER, CHEPSTOW

PROGRAMME OF OPENING OF CHEPSTOW BRIDGE, 1816.

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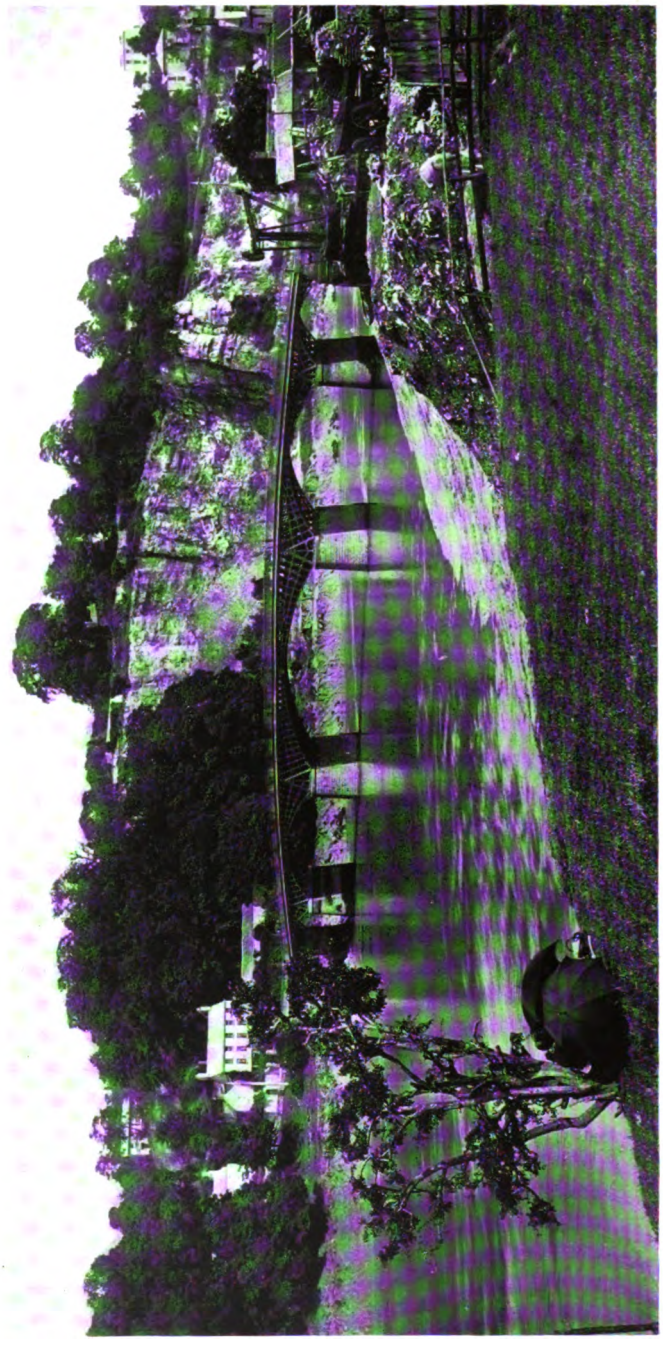
PLATE X.



RASTRICK'S CAST IRON BRIDGE AT CHEPSTOW
present day.

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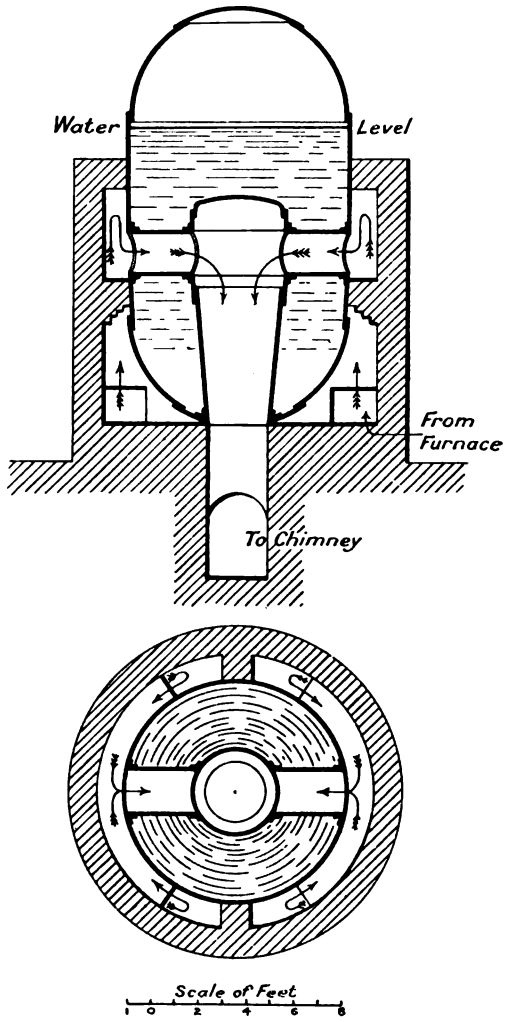
PLATE XI.



RASTRICK'S WASTE HEAT BOILER.

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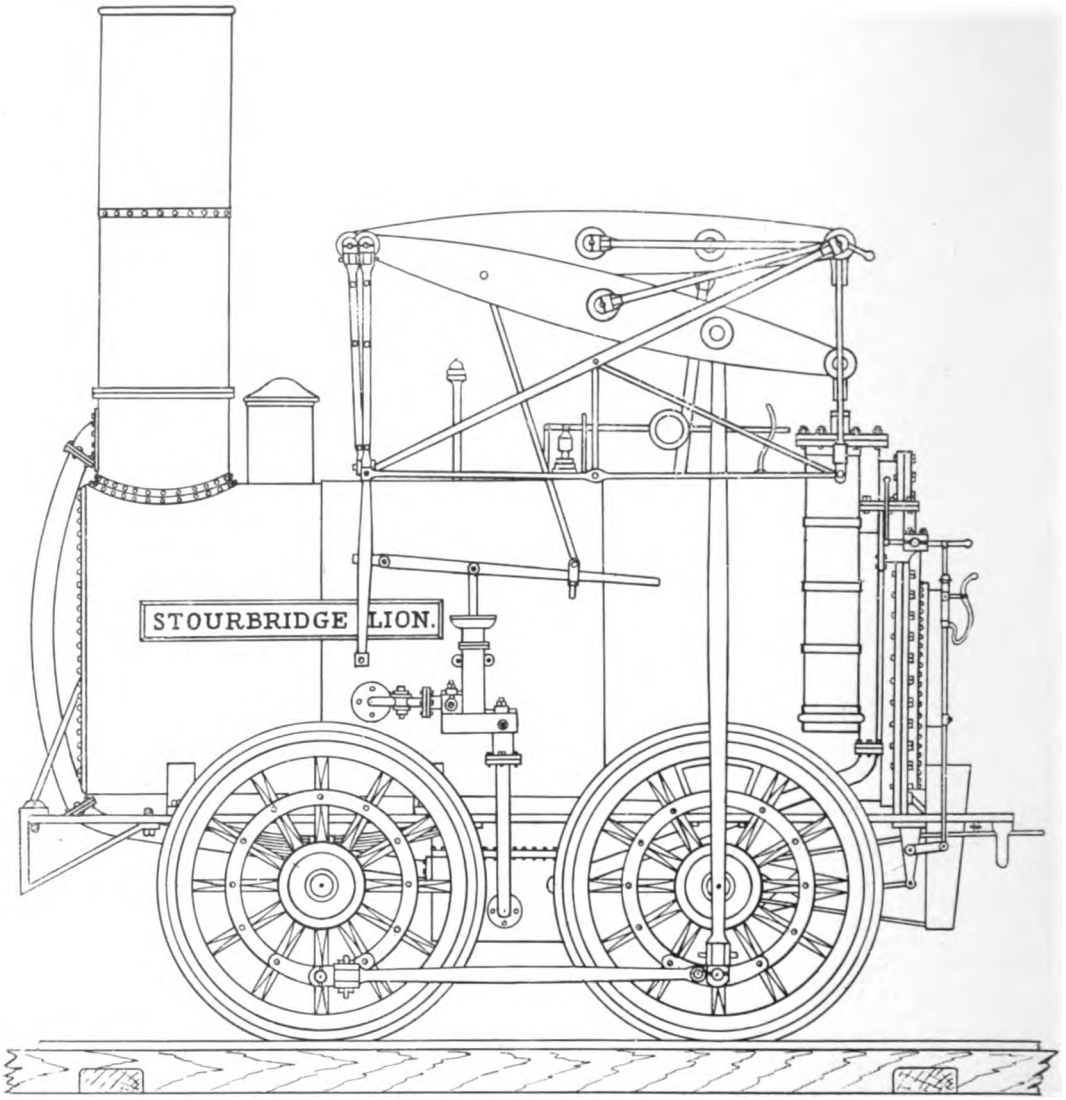

RASTRICK'S LOCOMOTIVE "STOURBRIDGE LION" 1829,
FOR THE DELAWARE AND HUDSON CO.
After an original drawing.

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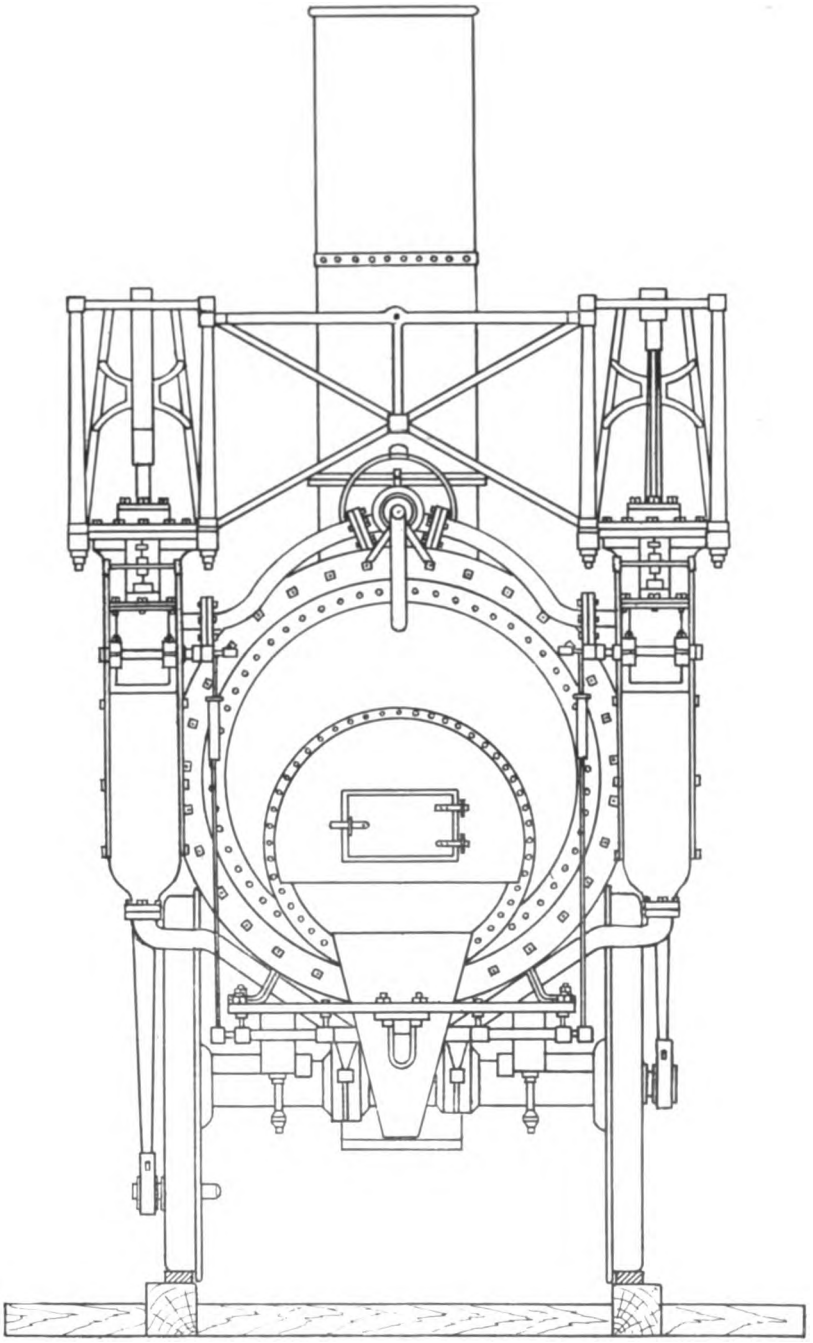
PLATE XIII.



RASTRICK'S LOCOMOTIVE "STOURBRIDGE LION" 1829,
FOR THE DELAWARE AND HUDSON CO.
After an original drawing.

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PLATE XIV.

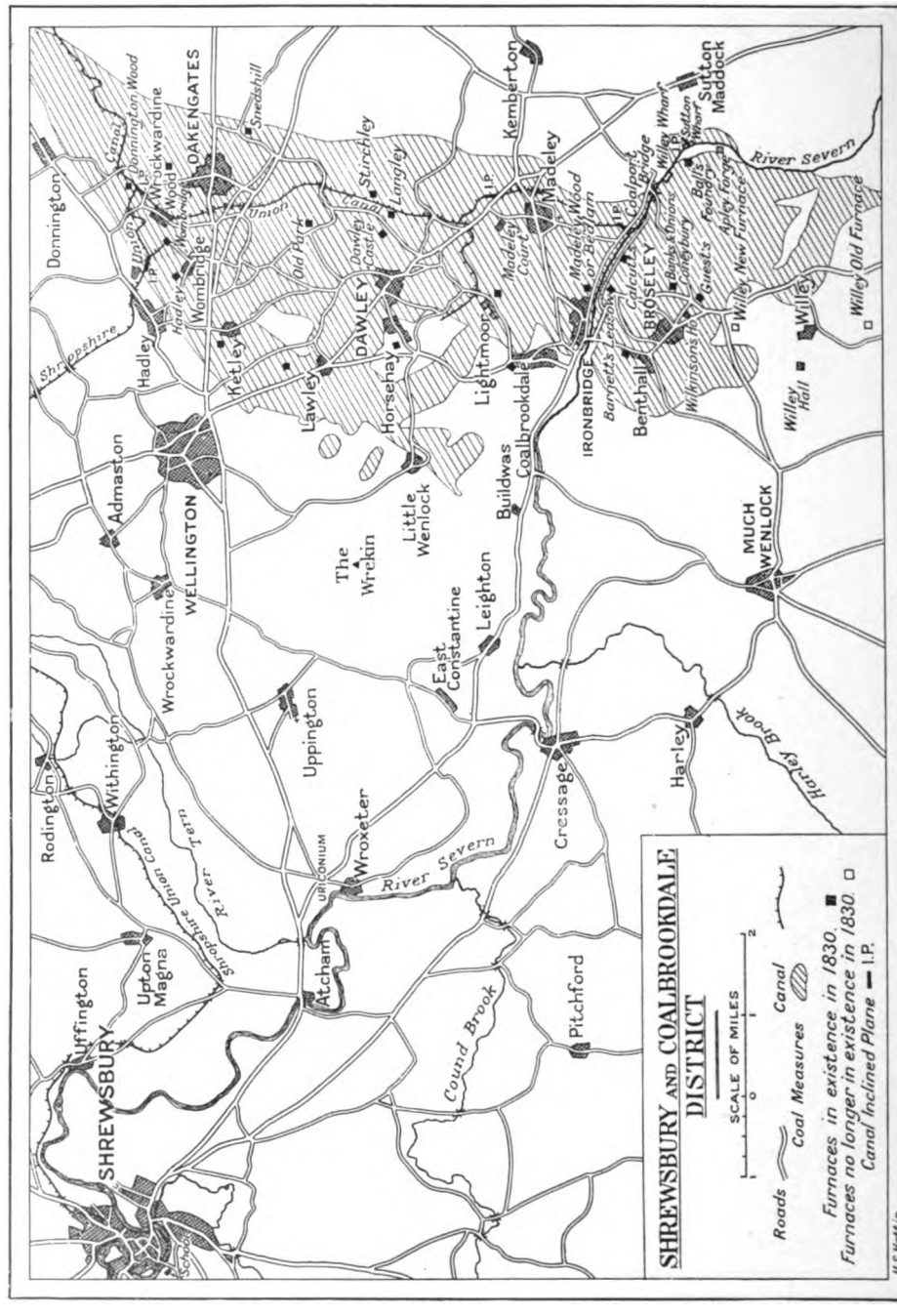
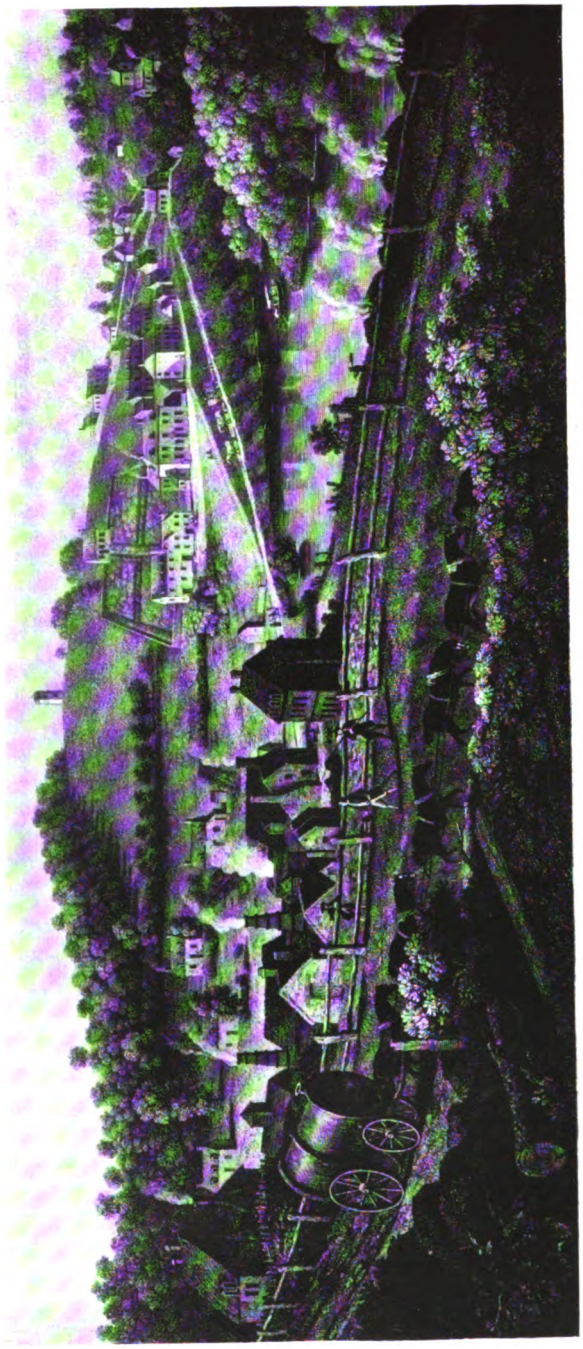

SHREWSBURY AND COALBROOKDALE DISTRICT
SCALE OF MILES
Roads
Coal Measures
Canal
Furnaces in existence in 1830.
Furnaces no longer in existence in 1830.
Canal Inclined Plane — I.P.
H.S. Hattin.
SHREWSBURY
Uffington
Upton Magna
Rodington
Withington
Wrockwardine
WELLINGTON
Admaston
Hadley
Donnington
Donnington Wood
Wrockwardine Wood
OAKENGATES
Wombridge
Hadley
Ketley
Lawley
DAWLEY
Horsehay
Old Park
Dawley Castle
Stirchley
Langley
Snedshill
Lightmoor
Madeley
Madeley Court
Madeley Wood or Bedlam
Kemberton
Coalbrookdale
Buildwas
Little Wenlock
The Wrekin
Leighton
East Constantine
Uppington
Wroxeter
URICONIUM
Atcham
Cressage
Harley
Harley Brook
Pitchford
Cound Brook
Shropshire Union Canal
River Tern
River Severn
Shropshire
Union Canal
Coalport Bridge
Calcutts
Barnetts Ledsom
IRONBRIDGE
Benthall
BROSELEY
Wilkinsons Ho
Banks & Onions
Coneybury
Guests
Balls Foundry
Apley Forge
Willey New Furnace
Willey Wharf
Sutton Wharf
Sutton Maddock
Willey Old Furnace
Willey
Willey Hall
MUCH WENLOCK

PLATE XV.



"A VIEW OF THE UPPER WORKS AT COALBROOK DALE IN THE COUNTY OF SALOP"
from an engraving of 1758.

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PLATE XVI.

"A VIEW OF THE IRON BRIDGE IN COALBROOK DALE IN SHROPSHIRE"
from an engraving of 1788.

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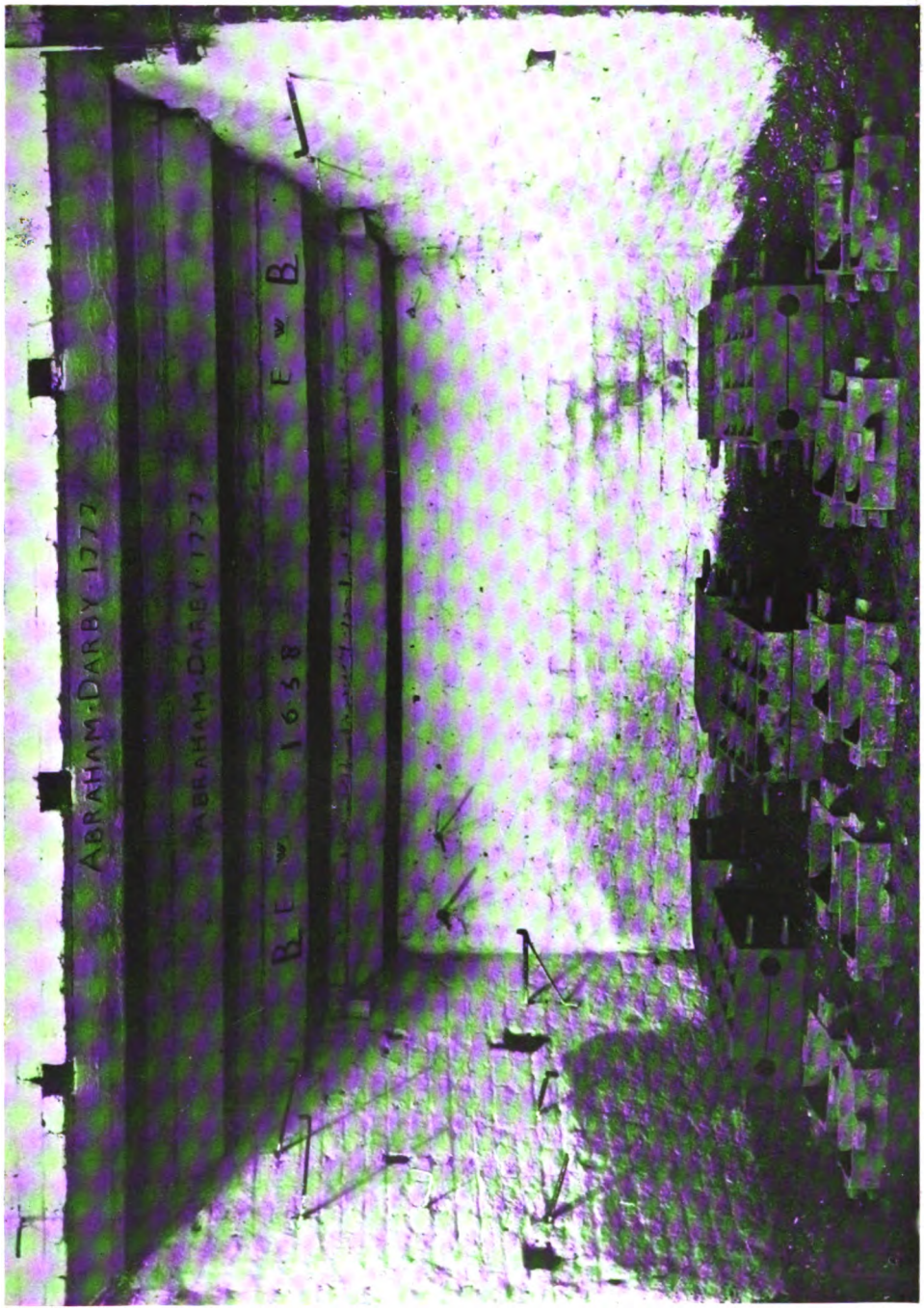

BEAMS IN BREAST OF DISUSED BLAST FURNACE AT COALBROOKDALE.

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PLATE XVIII.

VIEW OF MOULDING FLOOR FROM THE FURNACE, COALBROOKDALE, SEEN IN THE PRECEDING PLATE.

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PLATE XIX.

VIEW IN OLD MOULDING SHOP, COALBROOKDALE,
showing foundry cranes, &c.

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EARLY WATERWHEEL AT COALBROOKDALE.

COALBROOKDALE COPPER TOKEN, 1792.

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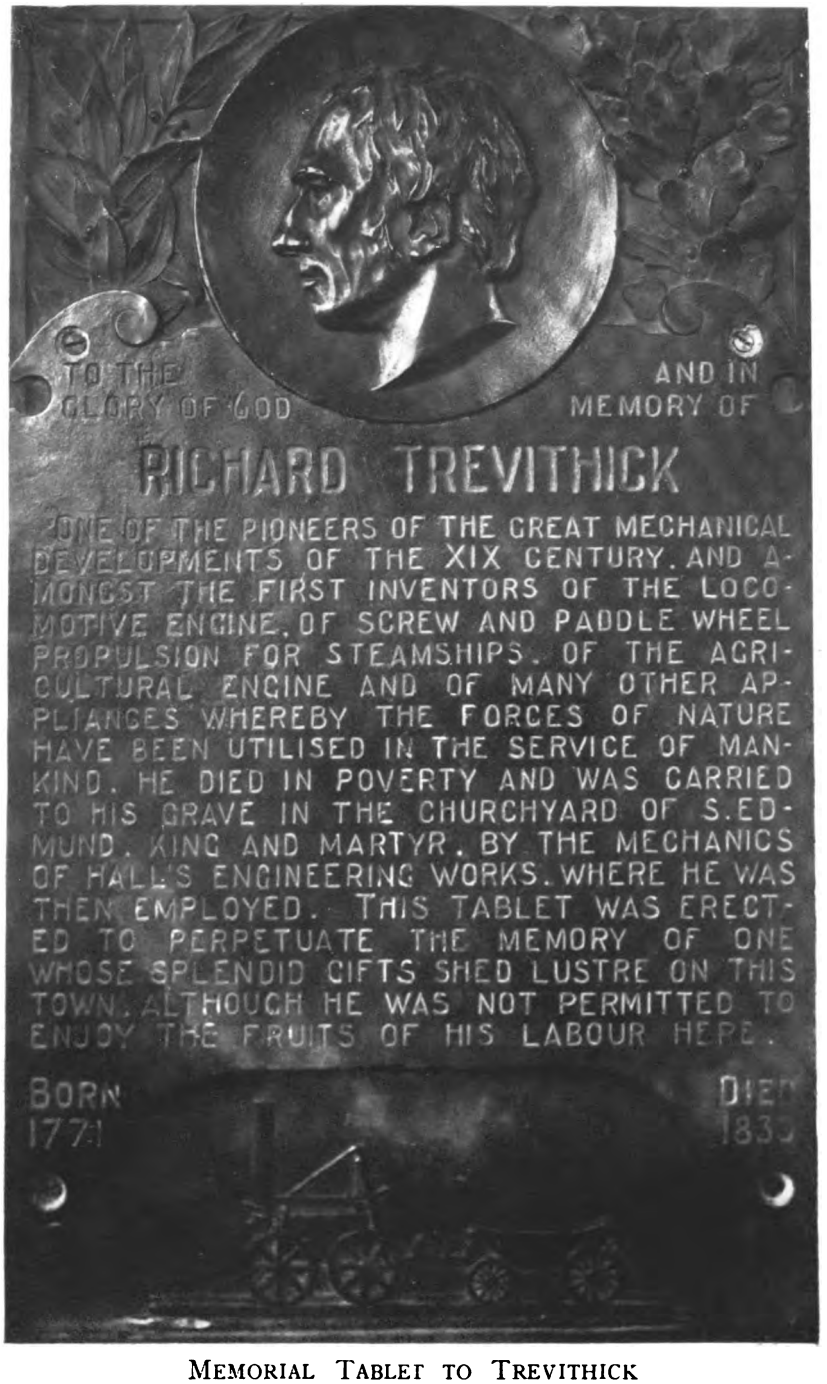

MEMORIAL TABLET TO TREVITHICK
in Dartford Parish Church, Kent.

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